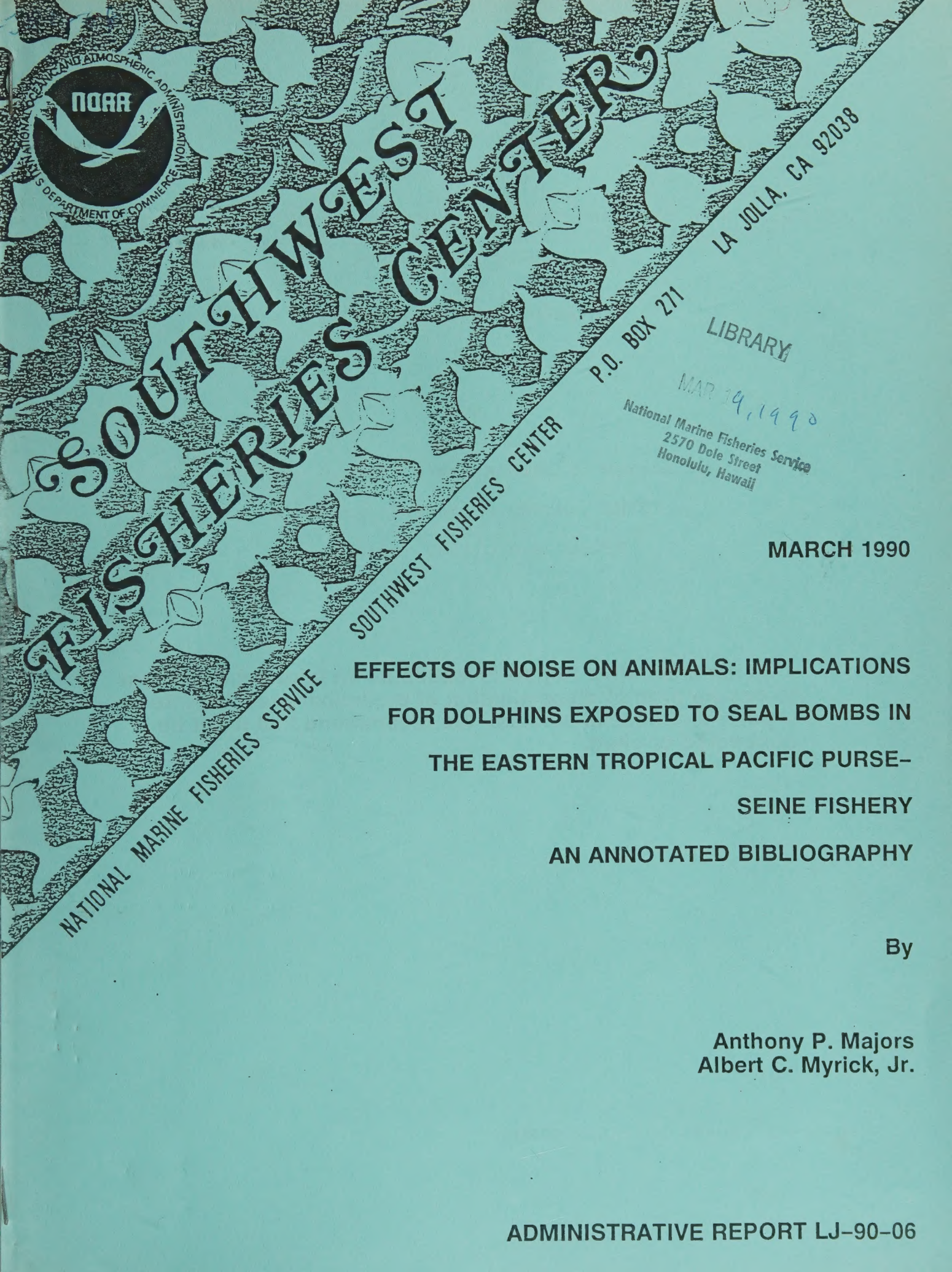




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EFFECTS OF NOISE ON ANIMALS: IMPLICATIONS FOR DOLPHINS EXPOSED TO SEAL BOMBS IN THE EASTERN TROPICAL PACIFIC PURSE- SEINE FISHERY AN ANNOTATED BIBLIOGRAPHY

By

Anthony P. Majors
Albert C. Myrick, Jr.

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EXPOSED TO SEAL BOMBS IN THE EASTERN TROPICAL PACIFIC
PURSE-SEINE FISHERY

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ABSTRACT

This literature review was conducted on studies dealing with audiogenic stress on laboratory, domestic, and wild animals. Noise stress is known to produce disturbances in various biochemical and physiological activities in animals and humans. Lethality usually depends on the intensity of the noise measured in decibels (dB)¹. In the purse-seine fishery, use of seal bombs to control dolphins in a set is hypothesized as potentially stressful to these animals. Although available information has not provided any indication of harmful effects of noise on dolphins, there is concern that exposure of these animals to exploding seal bombs and other type noises associated with fishing operations may have permanent adverse effects on social behavior, physiology and reproduction.

INTRODUCTION

Since the early 1950s, yellowfin tuna, Thunnus albacares, in the eastern tropical Pacific (ETP) have been harvested with purse seines, making the fishery one of the most successful tuna fisheries in the world. Fishermen locate schools of dolphins and encircle them with purse-seine nets to catch tuna that follow these animals (Perrin 1969). Small hand-thrown explosives known as seal bombs were used at least as early as 1980 to control dolphins during the chase, to prevent them from escaping open parts of the net during encirclement, and to facilitate dolphin release during backdown. These devices have since become an important part of "porpoise fishing" by many skippers (Cassano et al. 1990).

There is concern among naturalists, environmentalists, biologists and those in the fishing industry that impulse noise generated by these exploding devices, as well as noise from the seiner, skiff, and speedboats, may be stressful and might have long-term adverse effects on dolphins. Unfortunately, very little is known about audiogenic effects on these animals. Field studies that might use explosives or recordings of noise generated from such operations on dolphins are not envisioned because of requirements of both the 1972 Noise Control Act and the Marine Mammal Protection Act. It is the intent of this review to examine the evidence for audiogenic stress in laboratory, domestic and wild animals to evaluate the stress that might be imposed upon dolphins exposed to seal-bomb explosions and other types of noises associated with "porpoise fishing."

¹Unless otherwise indicated, amplitude for air-borne and water-borne sounds is in decibels with reference to 20 μ Pa (micro Pascal) and 1 μ Pa, respectively. For conversion from 20 μ Pa to 1 μ Pa, add 26 decibels (Evans 1982).

OBJECTIVES

The purpose of this study was to collect and review published and unpublished reports on effects of noise upon laboratory and domestic animals, wildlife, and on humans who are frequently exposed to noise as "stressors." Because there are virtually no field observations on the effects of noise on dolphins in "porpoise fishing," we trust that studies and observations presented in this report may foster greater appreciation of the problem and also guide future studies of noise effects on dolphins.

LITERATURE REVIEW PROCEDURE

Manual and computer searches were applied in this study. Table I lists keywords used to facilitate and quantify the many related subjects pertinent to noise effects on the observed species. Manual search involved reviews of bibliographies and literature citations from various publications and indices. Computer searches involved linking with and searching the following Dialog databases: Biosis, Zoological Record, Congressional Record, and Federal Register Abstracts. Unpublished materials were obtained by several methods including letters, verbal and telephone communication. Subjects selected for this search include: 1) animals in their natural habitats, 2) animals observed and then sacrificed in laboratories for quantitative and qualitative analyses, 3) wildlife affected by industrial noise and human encroachment, and 4) clinical studies on humans.

SYNOPSIS OF FINDINGS

Although most studies dealing with audiogenic stress have been on laboratory animals, some studies have been conducted on domestic and wild animals and on humans. Many of the common diseases and ailments that affect humans, such as pulmonary, cardiovascular, and neuroendocrine maladies, often have been found to be associated with a patient's physiological stress response to noise via the sympathetic or parasympathetic systems (Selye 1943, Medoff and Bongiovanni 1945, Jurtshuk et al. 1951). For the most part, studies have focused on the effects of noise as stressor on: (I) social behavior, (II) masking, (III) non-auditory physiological functions, and (IV) productivity in farm animals.

Social Behavior

Natural reactions of animals to sound depends on the loudness, duration, frequency, and source of the noise. The "fight-or-flight" reaction by those within hearing range will also depend on whether the sound is expected and if there are other stressors associated with the noise (e.g., predators, humans or other physical factors). Noise may affect or alter the

behavior of an individual animal, the entire herd, flock or school (Busnel 1968).

There is considerable information on animal responses to noise. Data are sufficient to predict what certain animals would do when frightened by an unfamiliar or loud noise. Caged and domestic animals may display unusual behavior because they are unable to escape (Anthony and Harclerode 1959, Gray 1982). Frightened and startled domestic and wild animals exhibit abnormal behavioral patterns (aggression, refusal of food, cessation of grooming, and altered reproductive behavior), weakened reflexes, avoidance (vacate habitat, change home range or alter migration pattern), or show impaired learning and physical performance (Monaenkov 1958, Hepworth 1966, Rosen 1970, Deryagina et al. 1976). Klein (1971) noted that reindeer exposed to the humming noise of power lines had difficulties in herding. Kucera (1974) observed that mammals subjected to noxious noise responded by altering their migration patterns, and changing home ranges and behavior patterns, including refusal to or not being able to mate. Sprock et al. (1967) found that wild rats and mice exposed to 60-140 dB at 100-25,000 Hz avoided nesting near the sound source and died when exposed to highest noise intensities. Persistent noise usually causes animals to leave certain habitats and sometimes avoid them permanently (Dufour 1980).

Greves and Rowe (1969) found that colonies of Norway rats and house mice subjected to pulsed ultrasound (>20 kHz) for 76 and 81 days respectively displayed aversion to the noise and avoided the testing area. Monaenkov (1958) subjected rats to electric bell noise from 45-120 minutes per day for seven days and found them to be aggressive, untidy, less active and refusing to take food. Trained white rats exposed to noise of 85 dB displayed weakened conditioned reflexes (Borisova 1960).

Groh (1965) studied the effect of noise and crowding on learning behavior, physiological change, and autonomic response of 80 albino rat pups. The pups were raised in litters of three or 13 animals for 42 days. The investigator observed that noisy and crowded conditions independently produced behavioral changes. Pups raised in large groups weighed less and had larger adrenal glands. Those raised in small litters (sound exposed, 50-60 dB) and those raised in large litters (sound insulated) exhibited decreased activity and increased heart-rate responses in open field tests. In contrast, pups raised in smaller litters and in sound-proofed boxes learned faster, were responsive in open field tests, and had normal heart rate.

Rabbits exposed to sounds of 94-96 dB at 3,000 Hz 4.5 hours a day for 14-28 days, were reported by Deryagina et al. (1976) to be aggressive, frequently fighting each other and exhibiting fright reactions. Soom et al. (1972) outfitted seven wild rabbits with radio transmitters and observed their movements when subjected to snowmobile noise. The investigators found that the animals exhibited increased movements and expanded their home ranges during snowmobile runs. These home ranges were decreased

significantly when snowmobile runs were terminated. Crummett (1970) studied the responses of wild rabbits to noise by subjecting them to a commercial noise production unit. He found that an acoustical signal at 2,000-4,000 Hz given off by the unit successfully repelled these animals.

Carnivores are not immune to noise stress. McCourt et al. (1974) observed that bears exhibited fright reaction and fled when airplanes flew over at 1,000 feet (ft). Doll et al. (1973) reported that wolf and coyote were frightened by aircraft that flew over at 25-100 ft. However, a family of coyotes was observed (Ellis et al. 1978) playing and feeding under high voltage power lines emitting constant noise of 65 dB. Klein (1971) and Mech (1970) also have reported that wolves can adapt to aircraft noise if they are not hunted from aircraft.

Hoofed mammals have been subjects of the most study among the larger species of the wild. Deer near Eglin Air Force Base showed no response to sonic booms (Cottureau 1978). However, Moen (1976) hypothesized that deer were more susceptible to noise during the winter months (Jan-Mar). Moen felt that noise disturbances from sources like snowmobiles may cause increased activity that has a depleting effect on thermal energy reserves. Soom et al. (1972) studied this problem by placing radio transmitters on eight deer. These animals were exposed to six snowmobiles operating one to four hours each afternoon for eight days February and March in a 140-acre tract. One deer left the area on the first day and returned on the following day. In addition, there was above normal movement among the animals. The investigators concluded that exposure to sonic booms was less disturbing to these animals than were snowmobiles with human operators.

Unlike coyotes, reindeer were found by Ellis et al. (1978) to avoid noisy electric power lines. But the investigators also observed bighorn sheep sleeping and feeding near lines emitting 53-dB noise and observed elk moving freely under lines emitting up to 63-dB noise. The observers concluded that the animals were not disturbed because the noise was in a regular, predictable pattern.

In advance of the proposed Arctic gas pipeline, Kucera (1974) studied the response of Dall sheep to simulated gas-compressor noise of 107 dB at approximately 15 ft from source. The herd displayed altered behavior, abandoned their normal home range and moved to an area one mile away. Dall sheep were also studied by McCourt et al. (1974) and Feist et al. (1973) who found that these sensitive animals were more frightened by helicopter flyovers with noise of 60 dB than by gas-compressor noise.

Pronghorn antelope were undisturbed by flyover noise of 60 dB; these animals, however, showed strong fright reactions and fled the area when exposed to flyover noise of 77 dB (Luz and Smith 1976). Kucera (1974) observed that moose were frightened

by fixed-wing aircraft flyover noise at 200 ft and lower. He also found that Canadian musk oxen were quite disturbed by snowmobiles to which they responded with aggressive behavior and flight from the area. Roseneau and Warbelow (1973) estimated that musk oxen may shift 16 miles from their home range due to flyover noise. Caribou were observed by Jakimchuk et al. (1974) to be very sensitive to flyover noise, especially when in rut. A herd of 30,000 stampeded when frightened by helicopter flyover noise from 500-1,000 ft. Caribou were also observed by McCourt (1974) to avoid gas compressor noise and to live only in areas at least 1.5 miles away from stations.

Bats avoid noise. Hill (1970) observed these flying mammals avoiding high frequency sound of 4-15 kHz from 12 adjustable dog whistles. The noise was used to scare away 500-1,000 of these animals from a nuclear power plant.

Rhesus monkeys exposed to sound of 100 dB displayed less social contact when placed with a small group of unexposed monkeys (Hanson et al. 1976). Similar results were reported by Nealis and Bowman (1977) when they subjected Rhesus monkeys to one and five hours of continuous noise and five hours impulse noise of 100 dB.

Busnel and Lehmann (1978) studied the effects of audible and inaudible acoustic stimuli in normal and deaf mice. These animals were subjected to high- (500-10,000 Hz) and low- (5-50 Hz) frequency-white noise for two hours and then tested for swimming time in a tank of water. High-frequency noise reduced the swimming time of normal mice, but not the deaf mice. Low-frequency sound, at 106-115 dB, reduced the swimming time of both hearing and deaf mice. Conduction of sound was infrasonic (below audio-frequency range); thus, sound transmission was interpreted to be through visceral and bone pathways.

A Committee on the Problem of Noise (1963) reported that noise of 85 dB is sufficient to scare away birds. Sonic booms were not found by Cottereau (1978) to affect birds dramatically. When studying 20 wild turkeys using telemetry, Lynch and Speake (1978) observed that turkeys stopped their activities during booms, and resumed their normal behavior after a few seconds. In Wales, England, Davis (1967) found that sonic booms frightened ravens and caused them to form large flocks in numbers and to fly in circles. Shaw (1970, 1978) observed that adult condors were very sensitive to noise and abandoned nests when disturbed by blasting, traffic, and sonic-boom noises. In Dry Tortugas (Florida), Henkin (1969) and Bell (1970) reported that the most damaging effect of sonic booms was when it caused mass hatching failures of sooty terns. After 50 years of breeding success, 99% of the eggs failed to hatch in 1969. Noxious noise from low-supersonic flights drove off the adults which left their eggs unprotected. The eggs were subsequently damaged. A similar situation was reported by Graham (1969) when observing the destruction of pelican eggs by gulls, after the pelicans were driven away by sonic booms. An environmental impact study for

the U.S. Department of the Interior (1969) on Big Cypress Swamp Jetport rated jet-overflight noise as 75 and 97 dB at 3,000 and 500 ft, respectively.

In Canada, Jacobson (1974) reported that fixed-wing aircraft flying at 5,000 ft caused Canada geese a half-mile away to flush and that construction noise caused six falcons to abandon nests. He also observed the devastating effect of helicopter overflight noise which scared away nesting geese, leaving their eggs unprotected, to be destroyed by jaegers and gulls. Gollop et al. (1974) noted that Canadian snow geese are quite sensitive to simulated gas-compressor noise. When subjected to the stimulus, they vacated the area and moved three miles away from the noise source. The authors concluded that the presence of this noise in the area also resulted in fewer geese landing near decoys.

Studies by Bondello and Brattstrom (1979a) showed that spadefoot toads (Scaphiopus couchi) of the U.S. southwest are quite sensitive to off-road vehicle (ORV) noise. Sound from ORV resembles thunder and has been observed to cause these burrowers to emerge earlier prior to the breeding season in the rainy months. To investigate the problem, 20 of the toads were allowed to burrow in 10 centimeters of sand in a 15 gallon tank. Recordings of ORV noise of 95 dB (re 1 μ Pa) played for periods 10, 20, and 30 minutes caused the toads to emerge from their burrows. Once emerged, the animals were unable to reburrow since their limited stored energy and water resources were expended when surfacing.

The 1970 FAO Fisheries Report stated that sudden changes in vessel noise levels frighten schooling fish. Malar and Kleerekoper (1968) subjected goldfish to various noise intensities (2,000 Hz, 30 cm from the noise source) and concluded that their locomotor patterns were affected significantly at 80 dB (re 1 μ Pa). Fine and Lenhardt (1980) studied the underwater vocalization of Opsanus tau and found that this oyster toadfish is quite sensitive to noise. The male ceases its mating call when exposed to underwater disturbances. The investigators suggested that noise is capable of disturbing courtship in toadfish and may also affect fishes of commercial value.

Honeybees were found by Frings and Little (1957) to discontinue movements for 20 minutes when exposed to 107-119 dB at 300-1,000 Hz and were unable to habituate to the stimulus even two months after sound exposure. Experimenting with these insects again in 1959, Little showed that noise 200-2,000 Hz produces discontinued movement in honeybees. Similar sound response was observed by Tsao (1969) on the Indian-Meal Moth when it was subjected to 2-40 kHz.

Masking

Masking is the inability of animals to hear and decipher signals and cues from members of its species and other animals because of background noise in the environment. Threshold audibility in a given time-area depends entirely on the spectra and intensities of each signal relative to the spectra and level of the ambient noise (Scott 1968). Animals depend on these auditory signals for orientation, locating mates, evading predators, catching prey, and finding and identifying young (Busnel 1968). Lee and Griffith (1978) noted that behavioral changes in animals due to masking is the most observable effect of noise. In addition, it was their opinion that continuous polluting of airwaves with noxious noise diminishes animals' ability to receive and respond to signals.

Auditory communication is widespread among animals. Mammals and birds use similar types of vocalization (Hooker 1968), fish make auditory signals, while insects produce noises through vibration of their wings on other body parts (Scott 1968). These vibratory stimuli may range from low-frequency signals made by fish and certain amphibians to high-frequency noises emitted by many insects and some dolphins (Busnel 1968). Acoustic communication is used by almost all higher life forms, and is received and synthesized in a variety of hearing apparatuses.

Birds are quite capable of communicating over the noise of the colonies without adverse effects; the same is true of birds in the noisy jungle (Hooker 1968). Social birds like penguins, flamingos, ducks, and geese are able to discriminate sound stimuli so that communication can be effective in noisy habitats. For example, Potash (1980) studied Japanese quail and found that, when quail were isolated from their mates, they increased their "separation calls" from 36 to 63 dB and were recognized by their mates. However, authors like Thorpe (1969) and Myrberg (1978) warned that noxious background noise has the potential effect of masking signals in animals and may adversely affect processes such as spacing, nesting, care of young, and the predator-prey relationship.

Consider the predator-prey relationship negatively affected by masking in the case of the desert sidewinder (Crotalus cerastes) and the kangaroo rat (Dipodomys deserti) as reported by Bondello and Brattstrom (1979b). A kangaroo rat, when about to be preyed upon by a sidewinder, defends itself by kicking sand at the snake when it approaches for a strike. The investigators experimented with 14 rats and selected two. The two rats were subjected to dune buggy noise of 95 dB, at 4 m, for 500 seconds (25 sec. on, 5 sec. off). They found that exposure to the noise caused acute hearing impairment to the rats. The noise was so overwhelming to the exposed rodents that, even after a 10-minute time lapse, the rats could not hear the sidewinder's crawling noise of 36-38 dB from 10 cm. The crawling noise had to be increased 44-48 dB before it was detected by the rats. This is equivalent to having the distance of detection changed from 40 to

2 cm. Normal hearing sensitivity in the kangaroo rats was recovered in 21 days. However, this was sufficient time for a successful nocturnal attack by a sidewinder.

Masking may be more complex in aquatic than terrestrial species because of possible multiple receptor systems in aquatic animals (Popper and Fay 1973). However, there is little information available on fish masking since auditory communication in aquatic organism is not fully understood (Tavolga 1968). The variety of sounds produced by fish are used for intraspecific communication associated with feeding and reproduction. For example, sharks are known to detect and localize prey through sound, while male damselfish use sound in courting a mate and establishing territory (Myrberg 1978).

Marine mammals and bats are known to rely on auditory signals for survival (Griffin et al. 1963). For example, when the ambient noise levels interfere with communication in bats, the animals display an adaptive-masking-resistant behavior by orienting themselves so that noise and signals are received from different angles. Like bats, marine mammals use auditory signals and distance reception for locating mates, finding food, and avoiding predators.

Masking can be potentially hazardous in toothed whales and dolphins because acoustic signaling by echolocation is vital for survival (Myrberg 1978). In studies on porpoises and dolphins, Norris et al. (1961) observed that a blinded (eyes covered with rubber cups) Tursiops sp. navigates without error through a maze of diverse obstacles, while Busnel et al. (1965) observed a blinded Phocoena sp. as it detected metallic targets as small as 0.2 mm in diameter using echolocation. Signals in these animals, however, can be masked if perceived in a medium polluted with both natural (rain, wave action, etc.) and man-made (ship traffic, fishing operations, oil drilling, etc.) noises that can cause diminution in signal carrying power (Figures 1, 2, 3 and 4). For example, Shaw (1978) observed that fin whales, as a social unit, have been observed to use 20-Hz signals over several thousand miles to communicate with other members of the species. He suggested, however, that since signals emitted by these animals are within the threshold (10-500 Hz) of natural and man-made noises, these pollutants may have reduced the whales' communication distance.

Non-auditory Physiological Functions

Audiogenic stress has been found to affect other systems in animals. This may include physiological damage similar to those induced by heat, cold, pain, fear, and emotional distress (Lockett 1970, Lukas 1970, Myrick 1988). In the laboratory, a general stress response is induced when animals are exposed to crowding, fear, excess light, toxic substances, and noise (Groh 1965, Lehmann 1970). The usual response to stress is stimulation and activation of neural and endocrine hormones; this results in increased blood pressure, glucose and corticosteroid levels in

the blood, increased weight of adrenals, and changes in the digestive and respiratory systems. For example, a sudden warning noise or an unfamiliar sound by a member of the species can activate the sympathetic nervous systems of those within hearing range. This short-term physiological alarm (flight-or-fight reaction) is the animals' natural way of preparing the body for defense (Selye 1973, Moller 1975).

Exposure to continuous or intense noise is harmful to animals and humans (Anticaglia 1970). Noise affects the reproductive (Arvay 1970, Sontag 1970, Tamari 1970), pulmonary (Ponomar'kov et al. 1969), neuroendocrine (Anthony et al. 1959, Forster 1970, Kenneth and Bowman 1970) and cardiovascular (Arguelles et al. 1970, Gerber 1970, Rosen 1970) physiology. Additionally, it has been shown to affect certain biochemical parameters which may increase susceptibility to infection (Jensen and Rasmussen 1970) and seizure (Lehmann 1970, Sze 1970) in laboratory animals. Furthermore, noise may affect the quality of meat from domestic animals and reduce productivity from farm animals (Bond 1970, Ames 1974).

1. Resistance to diseases.

Stress may be measured in terms of released adrenocorticotrophic hormone (ACTH) in animals (Ames 1978). ACTH stimulates the adrenal glands and causes the release of cortisol and other corticosteroids, including aldosterone. Vander et al. (1975) defined stress as "anything that causes increased cortisol and sympathetic nervous activity." Selye (1936) described reaction of animals to stress in terms of alarm, resistance, and exhaustion.

Figure 5 is a stress response model drawn from Holvey (1972), Vander et al. (1975), and Selye (1976) which describes the sympathetic nervous system and cortisol activities during stress. From this figure it is possible to see that the "sympathetic system" response to stress, and the "parasympathetic nervous systems" regulate internal body functions. The two systems make up the autonomic (involuntary) nervous system which controls cardiac and smooth muscles of internal organs and glands, and maintains body homeostasis. The function of cortisol under normal conditions is to regulate metabolism of protein and carbohydrate, water and electrolyte balance, muscle tone and gastric secretion (Arguelles et al. 1970). Increased cortisol in stressed animals can result in increased blood sugar, fatty acids, prolactin (which induces lactation), thyroxine (which promotes growth), aldosterone/antidiuretic hormone (ADH; which increases water retention), vascular activity, protein breakdown and electrolyte imbalance. Stressful periods can result in decreased secretion of estrogen, insulin, LH (luteinizing hormone), FSH (follicle stimulating hormone), and testosterone (Holvey 1972, Selye 1976). Activities of the sympathetic system prepare the animal's physiological body functions when confronted with a "fight-or-flight" reaction which can last for

up to 48 hours. However, if stress continues, the animal will eventually be overwhelmed and experience exhaustion (Selye 1936).

Vander et al. (1977) found that stress reduces inflammatory response and antibody production in the blood. When experimenting with Swiss Webster BRVS mice, Jensen and Rasmussen (1970) demonstrated a significant difference in leukocyte counts following immediate and transitory responses of mice to noise. Mice exposed to noise of approximately 120 dB at 800 Hz three hours daily for seven weeks were more susceptible to viral infection than those that were in a control group. Each exposure was characterized by decreased number of leukocytes (leukopenia) followed by increased number of leukocytes (leukocytosis) in the blood. Mice inoculated with the vesicular stomatitis virus (which causes eruptions in the mouth) before exposure were more susceptible while those inoculated after exposure were more resistant to infection. In addition, Jensen and Rasmussen sound-stressed mice were more susceptible to the polyoma virus and produced more tumors than the non-stressed ones.

2. Seizure.

Autogenic seizure has been observed in various animal species, including humans (Kenneth and Bowman 1970, Krushinsky et al. 1970, Sze 1970). Audiogenic seizure syndrome exhibited by exposed animals is described in four successive stages: 1) wild running culminating in a series of stiff-legged bounds, 2) subject falls on its side with all four limbs jerking rapidly in a "clonic" convulsion, 3) a "tonic" seizure takes over when hind limbs slowly descend to a fully extended position, and 4) death to the animal as a result of respiratory failure. Although this type reaction may appear stronger than normal and seems pathologically beyond human experience, Lehmann (1970) pointed out that mucicogenic epilepsy can occur in humans. According to Forster (1970), approximately 1.0% of the population is known to have experienced reflex epilepsy when exposed to sudden loud noise. Symonds (1959) estimated that 6.5% of epileptic patients exposed to sudden and unexpected noise experienced a minor seizure which usually resulted in loss of consciousness.

Although harmful effects of noise to the nervous system is not established, various amino acids and biogenic amines have been implicated in neurochemical mechanism of audiogenic seizure. Lehmann (1970) concluded that serotonin, norepinephrine, and Gamma-amino-butyric acid (GABA) are involved in audiogenic-induced seizure. Sze (1970) show that GABA had a role in the development of seizure in mice. Studies on motivational stress by Lazovik and Patton (1947), who were experimenting with forced reaction associated with magnesium deficiency concluded that "conflict" situation was ineffective in inducing seizure in magnesium-deficient rats. Adrenalectomy experiments on domestic and wild Norway rats by Griffiths (1948) also failed to demonstrate lethargy and non-emotionality in animals as primary factors in determining seizure susceptibility.

Studies by Kenneth (1967) and Jumonville (1968), however, showed that sound-resistant mice, C57BL/6J, could be made highly susceptible to auditory stimuli on day 28 of age when exposed to intense noise on day 19 after birth. Independent studies by Lehmann and Sze in 1970 identified decreasing amounts of GABA in the brain of sound exposed C57BL/6J. This was recognized as possible cause of susceptibility to seizure in the tested resistant-strain mice. Reduction in the amounts of GABA in the brain when sensitized by noise as possible cause of susceptibility to seizure has also been recognized and reported by others like Balzer et al. (1960), Buchel et al. (1961), and Lehmann and Busnel (1963).

Although seizure can be evoked in animals by chemical, electrical, and sensory technics, Fink and Iturrian (1970) have found that sound produced the most frequent cases of convulsion behavior in certain strains of rats. Factors contributing to sound susceptibility of rats may include: genetic constitution, hormones, nutrition, audition, age (Fuller and Collins 1970), environmental influences, and behavior of individual animals (Gregory and Iturrian 1970).

3. Reproduction.

Audiogenic stress is known to affect reproductive functions in most animals, including humans (Sontag 1970, Carole et al. 1976). In humans, first menses presents itself sooner in city girls and those engaged in intellectual activities than in village girls (Arvay 1967, 1970). Tamari (1970) observed that exposure of pregnant females to sound which does not elevate the ambient uterine sound level may, nevertheless, affect the course of pregnancy by way of the central nervous system. In searching for answers, investigators have experimented with and subjected various animals to different levels and characteristics of noise hoping to establish a threshold of vulnerability by fetus and mother to audiogenic stress.

Anthony and Harclerode (1959) exposed 19 sexually mature male guinea pigs (16 wks old) to intense low-frequency noise of 139-144 dB at 300-4,800 Hz, 20 minutes on and 10 minutes off, 12 hours daily for six weeks. There was no reduction in sexual performance, no gastrointestinal ulcerations or pathology in the reproductive organs. The decrease in weight of adrenals, involuted thymus and stomach constrictions suggested to them that the limit of tolerance in the animals was being approached. They also pointed out that noise exposure is known to cause increased adrenal activity in humans. Common symptoms of auditory effects of noise may include: nausea, fatigue, headache, loss of neuromuscular coordination and reduced sexual libido. These symptoms are usually found among persons working around aircraft.

Zoric (1959) exposed 38 male mice to the sound of an electric bell eight hours a day for 21 days and found that the animals suffered shrinkage of the seminal epithelium, partial

blockage of first order spermatocytes, formation of teratocytes, and atrophy of the epithelium.

Audiogenic stress also affects offspring of laboratory animals. Ishii and Yokobori (1960) found that female mice exposed to white noise of 90-110 dB for six hours a day from day 11-14 of pregnancy developed more stillborn and malformed young, and smaller embryos than the unexposed mice.

Zondek and Tamari (1964) and Zondek (1964) experimenting with effects of audiogenic stimuli on reproductive organs exposed 48 mature rabbits and 3,100 mature and young rats to alarm-bell noise of 100 dB at 4,000 Hz and 95 dB at 10,000 Hz, one minute of every 10 minutes, 24 hours a day for nine days. The animals suffered enlargement of the ovaries, persistent estrus, and follicular hematomas. Effects were more distinct in female rabbits than in female rats. Investigators also found that audiogenic stimuli had hardly any visible effects in males of both species.

Zondek and Tamari (1967) subjected 482 rats to pure-tone noise of 80-90 dB at 10-40 kHz in the four-day mating and post-mating periods. They found that in contrast to the stimulating effect of auditory stimuli on sex organs, there was an inhibitory effect of noise on reproductive functions. Specifically, there was: 1) significant decrease in the capacity of males to fertilize and female to be fertilized, 2) significant decrease of fertility and productivity in those animals stimulated during the four-day mating period, and 3) significant increase in pregnancy interruption in those stimulated during post-mating period. They also found that reproductive functions in rats rendered deaf by kanamycin (an ototoxic drug) were not inhibited by auditory stimulation.

Singh and Rao (1970) exposed 74 adult female rats to 100 dB at 2,000 Hz continuously for 150 days. After 10 consecutive days, 31 animals developed persistent vaginal estrus, and more were affected with time. Fletcher (1971) reported that noise stress during the copulatory period enhanced fertility; unfortunately, it caused interruption in pregnancy during gestation.

Ward et al. (1970) reported that Swiss-Webster albino mice subjected to intermittent motorcycle-horn noise of 82-86 dB at 320-580 Hz, 35-45 minutes each hour 5-8 days during days 8-17 of pregnancy were affected pathologically. Approximately 40% of the litter was resorbed. The mean fetal weight of the exposed litter was 0.44 grams and the unexposed was 1.45 grams. Although sound pressure used in this study was moderate, investigators found that pregnant mice exposed to the stimuli during days 7-8 resulted in 100% fetotoxicity by day 18 of pregnancy. Stress affects the endocrine system of the mother and fetus. Release of catecholamines and steroids from the adrenals resulted in limited uterine and placental blood flow which caused fetal hypoxia and

delayed implantation. Teratogenic effects found in the litters were cranial hematoma, dwarfed hind limbs, and tail defects.

Kimmel et al. (1976) studied the effects of noise in offspring of pregnant mice and rats exposed to white noise of 100 dB at 20-20,000 Hz. Mice were subjected to noise during days 3-6, 7-10, and 11-14 of gestation and the rats during days 6-15. Fetotoxicity was significantly high among pregnant mice but there was none among rats. The mice gained significantly less weight during pregnancy among those exposed during days 3-6 and 11-14. Similar results were obtained for rats exposed during days 6-15. The authors surmised that predictability of noise used in these studies may have lessened teratogenic effects.

To determine whether other stressors acting along with noise affect the reproductive process, Busnel and Molin (1978) experimented with a combination of noise, vibration, and crowding on pregnant mice. They also wanted to know if results were due to direct stress effects on the fetuses or indirect stress effects on the pregnant mother. The study was done on: 1) Swiss albino males mated to females of the same strain; 100% of adults and young have normal hearing, 2) hybrid males carrying deafness recessive genes mated to deaf mutant females; 50% hearing and 50% deaf young, and 3) deaf mutant males mated to hybrid females carrying deaf recessive genes; 50% hearing and 50% deaf young. Each of the three groups were subdivided into treatments: A) noise, B) noise, vibration, and crowding, and C) control (non-stressed). Mice in A and B were subjected to recorded subway noise of 105 dB for one hour four times a day. Mice in B were placed 20 to a cage on a shaking device for two hours a day. Treatments started on the day of mating and continued until the completion of the the sixth litter. The investigators found no significant differences among Treatments A, B, and C on mothers' weight, number of young in the litters, numbers of surviving to weaning, and sex ratio of the offspring. However, the mean weight gain of the litters was 27% lower in Treatment A and the first three litters of the hearing mothers in B. Noise alone did not affect the weight of deaf offspring. Time between litters was irregular in A and B but not in C. Incidence of miscarriage, resorption, and cranial and spinal malformations were common in A and B. Busnel and Molin concluded that noise in combination with other stressors had a greater effect than when applied alone.

Arvay 1970 (based on Arvay and Nagy 1956) subjected white rats to alarm-bell sound of 95 dB at 1,000-2,000 Hz five minutes of every hour for 42 days, while illuminating the cages with light of 1,900-2,000 lux (1 lx=.0929 foot-candle; thus, 176-186 fc) 24 hours a day. The combination of noise and light stimuli affected significantly puberty, fertility in the adult animals, viability of the fetus, and the number of malformations observed in the newborn.

When studying the embryo-fetotoxic and teratogenic potential effect of noise on rodents, Nawrot et al. (1980) subjected mice

to three noise paradigms and time: (1) very high intensity continuous noise (jet engine, 126 dB) from noon to midnight, (2) high intensity random onset "startling" noise (jet engine and alarm bells, 110 dB) four hours a day, and (3) very high frequency noise (rodent repelling device, 18-20 kHz) also from noon to midnight. The CF-1 pregnant mice were subjected to one of three noise paradigms from days 1-6 or 6-15 of gestation. The investigators found a significantly decreased pregnancy rate in all groups exposed to noise except for one subjected to noise paradigm (1) from days 6-15. Also found were significant embryo-lethal effects occurring in the group exposed to noise paradigm (2) from days 1-6, and significant fetolethal effects in the group exposed to noise paradigm (3) from days 6-15. Average weight of the fetuses in all noise exposed groups was less than those in the control, but the difference was only statistically significant in the group exposed to the "startle" noise combination from days 1-6.

Malformations have also been found among dolphins (Perrin et al. 1989). A collection of dolphin embryos, fetuses, and adults obtained from incidental kills on tuna boats maintained at the Southwest Fisheries Service (NMFS), La Jolla, California, include specimens with severe caudal regression, megalencephaly, omphalocele, cleft mandible, and hypoplasia of the maxilla and monozygotic twins. Little is known as to what brought about malformations in these animals. Although it may be difficult to identify causes of such malformations, effects of noise stress may be one plausible explanation.

4. Pulmonary.

Ponomarev et al. (1969) reported that dogs subjected to 0.6 to 3.5 second burst of white noise of 105-155 dB suffered pulmonary hemorrhages. After two hours of approximately 125 dB noise levels, the animals developed 3-mm-diameter hemorrhages which remained detectable 60 days after exposure. The investigators also discovered that increases in noise level resulted in increased numbers of hemorrhages, but did not increase the size of each site.

5. Neuroendocrine.

Many authors agree that organ-weight data are best evidence that noise is stressful to animals, especially laboratory animals (Ogle and Lockett 1966). For example, Sackler et al. (1959) subjected female Wistar rats weighing approximately 194 g to noise of 110 dB at 375-500 Hz for periods of 1-5 minutes. Appetite in exposed animals was reduced significantly. There was also significant reduction in liver weight, vascularity and weight loss in the uterus, partial inhibition of ovarian activity and adrenal hyperplasia (abnormal increase in cells). Werner (1959) found that continuous exposure of rats to a ringing bell (eight hours/day) resulted in hypertrophy (abnormal enlargement) in the pituitary and hyperactivity in the adrenal cortex (increased cortisol secretion). Hrubec and Benes (1965) also

experimented with effects of repeated noise on rats and found increased secretion of catecholamines in urine, free fatty acids in the blood, increased weight of suprarenal, and suppressed growth in the exposed animals.

Nayfield and Besch (1981) subjected New Zealand white rabbits and Wistar rats to white noise of 107-112 dB at 60-60,000 Hz in an acoustic chamber 1.5 hours daily for five days. Both species displayed increased adrenal weights. The rabbits had decreased spleen and thymus weights. The rats had leukocytosis and eosinopenia. In addition, the animals exhibited decrease food intake by the third day.

Adrenocortical stimulation was studied by Anthony and Ackerman (1955) and Anthony et al. (1959). The investigators exposed mice, rats and guinea pigs to noise of 110 dB at 10-20 kHz, 132 dB at 2-40 kHz and 140 dB at 150-4,800 Hz. Subjected animals exhibited adrenal hypertrophy and increased adrenocortical activity. Guinea pigs showed altered serum ascorbic-acid metabolism. Those exposed to 135 dB at 2-40 kHz for 20-40 hours per week (2-9 wks) had pathological damage to adrenals and other organs which is an indication of normal endocrine defense breakdown.

Because increased adrenocortical hormone secretion was known to cause decreased thyroid activities, Fell et al. (1976) studied noise stress effects on rats' thyroid glands. The animals were exposed to noise of 95 dB at 1,000 Hz 15 minutes twice each hour, eight hours during the day, for 12 weeks. Thyroid activity, measured by uptake of radioactive iodine (I^{131}), was suppressed in the first two weeks in females, and from 2-12 weeks in exposed males. Females had significantly reduced weight gains in the first two weeks, but males showed no weight-gain reduction until the sixth week. The researchers inferred that altered thyroid activity due to noise stress may have reduced the secretion of growth hormone from the anterior pituitary.

Brzezinska (1968) subjected rats to noise (unspecified) for two hours a day (on days 3, 6, 9, 12 and 15) and found that the exposed animals had increased acetylcholine (a synaptic neurotransmitter substance) concentrations. Amount of acetylcholine decreased to normal by day 15. Since stress is known to induce increased sympathetic nervous system activity, increased acetylcholine levels in the exposed animals came as no surprise to the investigators.

Primates have been subjects of noise-stress endocrine studies. Nealis and Bowmans (1977) experimented with effects of continuous noise (recorded power tools and land vehicles), variable noise (rock music), and impulse noise (randomly presented shotgun blasts, pistol shots, and machine gun blasts) on plasma cortisol levels in 12 Rhesus monkeys. Each animal was exposed to the three types noise averaging 100 dB in sessions of one, three, and five hours with resting period of 90 hours between treatments. Test animals were separated into three

groups of two males and two females each. The animals exhibited elevated plasma cortisol levels after one hour of exposure to all three types of noise. When the fear reaction passed, the monkeys were able to habituate physiologically to the noise. Similar findings were reported earlier by Hanson et al. (1976) on the 24 Rhesus monkeys that they subjected to 100 dB noise from power tools, pneumatic drills, snowmobiles, and machinery. Their study showed significant elevation of plasma cortisol level in the exposed animals.

6. Cardiovascular.

Animals exposed to an alarming stimuli will respond in what is termed by Selye (1936) "the general alarm reaction" or "general adaptation syndrome." This physiological response may include increased blood pressure, elevated serum lipids (free fatty acids, triglycerides and cholesterol), increased platelet aggregation and adhesiveness, peripheral vasoconstriction, and heart rate acceleration and deceleration (Borg 1981, Selye 1976, Buckley and Smookler 1970). Other symptoms included dilated pupils, closed eyes, apnea, muscle tension, gastric secretion, paled skin, nervousness, irritability, and anxiety (Rosen 1970).

In studying plasma renin activity and its relation to hypertension, Vander et al. (1977) subjected rats to broadband noise of 80-115 dB at 2,000 Hz for 30 minutes. The control animals on normal and sodium-free diets received no acoustic stimulation. Rats on the normal diet were compared to those given a sodium-free diet since increased renin activity stimulates sodium retention. Broadband noise at 115 dB increased significantly plasma renin activity in rats on normal diet and at 100 dB in those on sodium-free diet. Sodium deprivation reduced the noise exposure threshold and increased the renin-releasing response to noise.

Deryagina et al. (1976) studied atherosclerosis by subjecting rabbits to oral doses of cholesterol (500 mg cholesterol in 5 ml of sunflower oil) and noise of 94-96 dB at 3,000 Hz, 4.5 hours daily, with 30 minutes rest periods every 1.5 hour for 14-18 days. Those receiving cholesterol were given daily doses for 4.5-5.0 months. Animals receiving both were exposed to noise in the first 14 or 28 days. The authors found that noise exposure alone caused higher blood pressure, increased fatty acids and adhesiveness in the blood.

Effects of noise on blood pressure and heart rate have been under investigation for many years. Peterson et al. (1975) found that intermittent and continuous noise affects the cardiovascular system. Rhesus monkeys were monitored for 30 days for a baseline heart rate and then exposed to continuous urban noise of 78 dB, 12 hours daily for 30 days. The monkeys were exposed also to intermittent noise of 112 dB, eight times daily for 30 days. Increased heart rate and blood pressure was noted in response to both sound stimuli. A significant overall average baseline-blood pressure increase of 28% was observed.

To simulate the effects of industrial noise on humans, Peterson (1980) and Peterson et al. (1980) subjected adolescent female Rhesus monkeys to an eight-hour recording of industrial noise. Monkeys selected had initial blood-pressure levels at the 50th percentile for Rhesus. The recorded sound, averaging 85 dB, included impulse and continuous industrial noise, morning and evening transportation noise, household noise, and aircraft-overflight noise. For accurate measurements of blood-pressure levels, the animals were chronically implanted catheters. In nine months, the primates displayed elevated systolic blood pressure of 137 mm Hg compared to a predisposed average of 106 mm Hg, an increase of 29%. Similar increments were found in the diastolic blood pressure. Noise exposure was terminated for 30 days, but blood pressure levels did not show tendency to normalize.

7. Biochemical parameters.

Hematology and blood chemistry of animals exposed to audiogenic stress may be altered by noise (Cannon 1929, Selye 1971). Noise can cause changes in the cardiovascular homeostasis in humans and other animals resulting in adjustments to peripheral blood flow, heart rate, blood volume and pressure, and salt and water retention. These and other chemical processes are controlled largely by the autonomic systems and adrenal hormones (Borg 1981).

Gerber et al. (1966) studied physiological responses of rats to noise of 73-93 dB at 20-25 kHz in time durations of: 15-270 minutes, 19-96 hours, and 21 days. The stimuli were presented six minutes of every hour. The investigators found elevated serum cholesterol levels, increased ascorbic acid levels in the brain and eosinopenia. Elbowicz-Wariewska (1962) exposed guinea pigs to noise of 160 dB at 100-50,000 Hz 45 minutes daily for 30 days. The animals responded with increased lactic acid dehydrogenase (LDH) activity and higher pyruvic acid levels in the blood. Holvey (1972) noted that higher enzymatic discharges in the blood are a symptom of diseased cells. Elevated LDH is symptomatic of cardiac, liver, kidney, muscle, and brain disorders. Fatty acids increased significantly in the blood of female rats when exposed to noise of 95 dB from a transmitter generator (Hrubes 1964). Hrubes and Benes (1965) also found that rats exposed to noise of 95 dB secreted increased urinary catecholamines, had increased fatty acids in the blood, and had heavier adrenal glands.

Friedman et al. (1967) subjected 54 rodents to white noise of 102 dB (200 Hz) at intervals of one second, and to 114 dB (200 Hz) at intervals of three minutes, 24 hours each day. Thirty rats were exposed to noise for three weeks and 24 rabbits for 10 weeks. The animals were fed normal diets and were also given oil pills. Triglycerides in the plasma were significantly higher than in control rats during the second week; however, there was no difference between control and exposed groups at the end of weeks one and three. Plasma cholesterol and triglycerides were

much higher in the rabbits after four weeks of exposure to the noise. In addition, there were fat deposits in the irises of the eyes and higher cholesterol in the aortas. The investigators concluded that auditory stress produces changes in the metabolism of administered fat in rabbits, and is quite similar to responses resulting in obesity, by those with chronic hypothalamic stimulations.

Blood sugar in dogs was found abnormally high after the animals were subjected to noise. Treptow (1966), experimenting with blood-sugar levels in dogs, found increased glycemic reactions in canines (one and eight out of 20 trials) when subjected to noise of 80-87 dB for 5-10 minutes. These animals, however, were able to habituate and normalize by trial 20. Jurtshuk et al. (1951) subjected two groups of female rats to noise of 100 dB at 120 Hz, one minute daily for 11 days and five minutes for 15 days. Rats displaying greatest locomotor response upon cessation of stimuli had the lowest blood glutathione (oxygen carrier). The stressed animals exhibited greater adrenal weights and excess amounts of ascorbic acid in the blood plasma.

Farm Animals

Farm animals commonly exposed to noise have been a concern to farmers and researchers. In this section, considering noise effects on these animals, we discuss heart rate, feed utilization, hormonal secretions, reproductive effects, water and sodium balance, weight gain and general behavioral responses.

Milk production in 182 milk cows exposed to sonic booms within three miles of eight Air Force bases was studied by Parker (1960) who found no significant difference between herds close to the runway and those farther away. Bond (1956, 1970), however, concluded that cows exposed to exploding paper bags, every few seconds for two minutes failed to give milk. This resulted in only 70% of the normal production from the animals 30 minutes after stimulation. Also, according to Bond (1971), motorboat noise caused reduction in milk production, but did not affect growth of calves and heifers. Stadelman (1958a) and Casady and Lehamann (1967) noted that reaction was more pronounced to low flying aircraft than to sonic booms. The same reactions in cows were observed in flying paper, strange persons, and other moving objects. These observations prompted Fletcher (1971) to suggest that response is due more to visual and noise stimulation than to noise alone.

Ames and Arehart (1972) exposed lambs to three types of auditory stimuli: white noise, instrumental music, and intermittent miscellaneous sounds (IMS; e.g., band marches, cannons, diesel engines, electric motors, fire crackers, fog horns, jet/propeller aircraft, machine guns, rain, roller coasters, and stadium crowds) of 75-100 dB. Each exposure lasted 15-180 seconds (interspersed with quiet periods of 1-15 minutes) given over 11 hours each day. The experiment was set up into four periods of: 1) 21-day control in ambient noise of 45 dB, 2)

12-day test period in noise of 75 dB, 3) 2-day control in noise of 45 dB, and 4) 12-day test period in noise of 100 dB. Heart and respiration rates were measured before each exposure and after in intervals of 15 minutes, and one, four, and eight hours for 11 days.

Strong increases in heart rate were observed with exposure to all three types of noise at levels of 100 dB; however, less change was caused by music than the other two sources of noise. Respiration rates increased when habituated and non-habituated animals were exposed to all three types of noise and reactions seemed to depend on noise type than level. Panting was exhibited by lambs exposed to music and IMS. These physiological responses accompanied by increased ACTH levels, indicate that the animals were stressed (Ames 1974).

Digestive functions in sheep were affected by noise in a study by Harbers et al. (1975). Sheep exposed to IMS consumed less food, had increased urinary output and higher digestibility coefficients (increased amounts of food absorbed by the digestive system). The investigator suggested that neural and endocrine mechanisms were involved, but felt that the animals seemed to acclimate well to noises of 100 dB or less. Studies on the effects of noise on meat animals (Ames 1978) showed that meat of lambs exposed to IMS and white noise of 100 dB exhibited color changes.

Bond et al. (1963) exposed swine to recorded aircraft noise of 100-130 dB (15 sec. on, and 30 sec. off), four or eight times on each animal. Heart rates increased significantly in the animals and normalized 30 seconds after the stimulus was given. A group exposed to noise of 120 dB 12 hours daily for 98 days also exhibited increased heart rates. Greater increases were found in unexposed swine that were later exposed to noise of 110-120 dB at 400, 1,000 and 2,000 Hz. The investigators found that swine exposed to noise of 93 dB for several days showed excess secretion of aldosterone (from the adrenal glands), with severe retention of water and sodium in young castrated males. Those exposed to noise of 120-135 dB, 12 hours daily from weaning to slaughter at 200 lbs, showed no significant difference in rate of weight gain or food intake. They found no significant difference in sow and young exposed to aircraft noise for 12 hours daily for three days before parturition.

Stadelman (1958b) studied noise effects on chickens by experimenting with maternal behavior of 18 New Hampshire and Plymouth Rock hens. The hens were observed for broodiness and then separated in two groups with each hen incubating 12 eggs. The hens brooding under normal conditions completed the incubation period with all eggs successfully hatched. In those exposed to noise of 120 dB, all but one hen abandoned the eggs within two hours. The hen that completed the incubation had only one chick hatched from the 12 eggs.

PRIMING EFFECTS

Priming was described by Lazovik and Patton (1947) as a pathological convulsion seizure induced by having an animal exposed to audiogenic stress for a brief period of time. However, it was Kenneth (1967) and Jumonville (1968) who independently studied this phenomenon in seizure-resistant C57BL/6 mice and found that susceptibility to seizure can be induced in animals by prior exposure to noise during a sensitive period of postnatal development. This postnatal period of sensitivity in the C57BL/6 strain was reported by Sze (1970) as day 19 postpartum for mice 28 days old. Sze suggested also that the existence of such a sensitive period may indicate that induced-seizure susceptibility involve some neural changes inducible only during development of the central nervous system.

IMPLICATIONS FOR DOLPHINS

Dolphins in the ETP are exposed constantly to noise and other noxious stimuli in "porpoise fishing." In a single set, they are chased and prevented from escaping by use of helicopter, speedboat(s), skiff, vessel, net, and noise (Coe et al. 1972). When encircled by the net, the dolphins are forced to swim and sustain themselves in crowded conditions which are not natural to these pelagic, air-breathing animals. While confined, dolphins are exposed to such foreign objects as net webbings, floats, corklines, propellers, boat hulls (vessel, skiff, speedboats), and humans. During backdown operations, they have to survive the increased crowding, folds in the net and the continuous noise from engines and winches. Finally, these animals may be exposed repeatedly (in at least some sets) to impulse noises from multiple seal-bomb explosions (Cazano et al. 1990) when the devices are thrown from helicopter, speedboats, and other vessels.

A dolphin set usually lasts approximately 2-3 hours. In some sets, dolphins may be subjected to seal-bomb explosions which produce an instantaneous impulse noise 190 dB (re 1 μ Pa) at below 2,000 Hz (Aubrey and Thomas 1987). In this review, we discussed audiogenic stress experienced by laboratory, domestic and wild animals induced by air-borne pure tone or white noise 75-125 dB (re 20 μ Pa). Dolphins in the ETP, however, are exposed to noise from many sources including impulse noise which is much higher in intensity, and with a much shorter rise time and unpredictable frequency and duration. Because dolphins presumably are exposed to a variety of noxious stimuli in addition to extremely high sound pressure levels of exploding seal bombs, they are potentially vulnerable to stressful effects of noise in the purse-seine fishery.

Repeated exposure of dolphins to noise potentiating other stressors associated with "porpoise fishing" could have long-term affects on these animals. Norris et al. (1978) and Coe and Stuntz (1980) observed that, dolphins when encircled in the net display a "rafting" behavior in which the animals remain at the

surface or just below it for long periods of time with minimum swimming and no diving activity. This behavioral pattern can be likened to laboratory animals observed displaying cessation of movements when stressed. Laboratory studies on mice, rats and rabbits by Anthony and Harcerode (1959), Groh (1965) and Gray (1982) showed that noise induces anxiety and ataxia in these animals when stressed and frightened. They display abnormal social behavior and have altered physiological functions during time of stress when exposed to noxious noise. They are known to be more susceptible to infections and to convulsive seizure when exposed to noise 95 dB and higher. The stressed animals have also failed to reproduce at normal rates or have been found with significantly high fetotoxicity and malformations in young. Based on this review, we may expect very similar conditions to be present among members of dolphin populations involved in the purse-seine fishery.

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EFFECTS OF NOISE ON ANIMALS: AN ANNOTATED BIBLIOGRAPHY

Ames, D.R. 1974. Sound stress and meat animals. Pp 324-330. In: Livestock Environment: Proceedings of the International Livestock Environment Symposium. Am. Soc. Engineers, SP-0174, St. Joseph, MI.

Meat animals respond to the audio environment. Auditory threshold curves for cattle and sheep are similar to those of humans, but with maximum sensitivity at higher frequencies (7 kHz for sheep and cattle; 3 kHz for humans). Data indicate that sound type and intensity significantly affected daily weight gain in these animals.

Ames, D.R. 1978. Physiological responses to auditory stimuli. Pp 23-35. In: Fletcher, J.L. and R.G. Busnel (eds.), Effects of noise on wildlife. Academic Press Inc., NY.

This is a study on sheep to characterize the physiological responses of large domestic animals to the different environmental sounds. The animals were exposed to three different types of sound sources (white noise, music, and intermittent miscellaneous sounds) of 45-100 dB at 100-12,000 Hz. Measurements of dry matter intake, nutrient digestibilities, water metabolism, and nitrogen balance were taken. As was confirmed in previous studies (Bond 1962 and Casady et al. 1967), sheep were able to acclimate to intermittent sounds <100 dB. Auditory stimuli did not affect digestion or rumen motility in the animals; however, it was found that intermittent sounds stimulate and help digestion. Also, animals that were exposed to intermittent miscellaneous sounds drank more water and excreted more urine.

Ames, D.R. and L.A. Aredhart. 1972. Physiological response of lambs to auditory stimuli. J. Anim. Sci. 34:994-998.

The investigators exposed 350 female lambs to sounds of 75-100 dB at 100-7,000 Hz for 21 days to determine auditory threshold of these animals. The lambs were found to be most sensitive at 7,000 Hz. They showed evidence of physiological changes in respiration and heart rate, and increased adrenal output when exposed to noise. In addition, the investigators found that the lambs respond to stimuli according to noise type and intensity. Also important, is an animal's previous experience with a particular sound.

Anthony, A., E. Ackerman and J.A. Lloyd. 1959. Noise stress in laboratory rodents. I: Behavioral and endocrine response of mice, rats and guinea pigs. J. Acoust. Soc. Am. 31(11): 1430-36.

The behavioral and endocrine responses to noise of 150-4,800 Hz vary in the three species of rodents observed. Adrenal response supports the belief that noise can create physiological stress in these animals; however, the stressor response is compensated for by the endocrine system acting as a multiloop feed-back unit.

Anthony, A. and J.E. Harclerode. 1959. Noise stress in laboratory rodents. II: Effects of chronic noise exposures on sexual performance and reproductive function of guinea pigs. J. Acoust. Soc. Am. 31(11):1437-40.

Sexual performance of guinea pigs was unaffected by intense low-frequency noise of 142 dB at 300-4,800 Hz. However, there was increased activity in the adrenals and significant decrease in sizes of these glands. Lymphatic tissues (thymus and spleen) had reduction in weight, and stomachs had pits and constrictions resembling healed ulcers. Noise also induces anxiety and reduction of movements in these animals.

Anticaglia, J.R. 1970. Noise in our overpolluted environment. Pp 1-3. [Abstr.] In: Welch, B.L. and A.S. Welch (eds.), Physiological effects of noise. Plenum Press, NY.

Noise caused auditory problems by masking speech or damaging receptor cells in the organ of Corti. It disrupted rest, relaxation, and sleep and hindered performance. Exposure to intense noise in heavy industry affects the cardiovascular system and may cause health problems.

Arguelles, A.E., M.A. Martinez, E. Pucciarelli and M.V. Disisto. 1970. Endocrine and metabolic effects of noise in normal, hypertensive and psychotic subjects. Pp 43-55. In: Welch, B.L. and A.S. Welch (eds.), Physiological effects of noise. Plenum Press, NY.

Purpose of the study was to determine whether abnormal responses to noise were reflected by changes in amounts of catecholamines and corticoids in individuals with abnormal circulatory conditions such as cardiac infarction, and hypertension in psychiatric patients. Cardiac infarction patients responded with increased norepinephrine. Significant amounts of epinephrine and norepinephrine were present in normal and hypertensive patients.

Arvay, A. 1967. Effects of exteroceptive stimuli on fertility and their role in the genesis of malformations. Ciba Found. Stud. Grp. 26:20-28.

The investigator found that induced sound stress influenced time of puberty and fertility in adult animals, and viability of fetuses. Intensive exteroceptive sound stimuli also significantly influenced the number of malformations in rats.

Arvay, A. 1970. Effect of noise during pregnancy upon fetal viability and development. Pp 91-115. In: Welch, B.L. and A.S. Welch (eds.), Physiological effects of noise. Plenum Press, NY.

In this study, rats were exposed to sound (1,500 Hz), light (1,250 lux) and reflectors (1,950 lux). The traumatized females gave birth to a remarkable number of young with congenital malformations. Of the three stressors, sound stimuli dominated as primary cause of malformations in the observed animals. Author pointed out that the relation between psyche and sexual functions is closer in females than in males.

Awbrey, F.T. and J.A. Thomas. 1987. Measurements of sound propagation from several acoustic harassment devices. Pp 85-104. In: Mate, B.R. and J.T. Harvey (eds.), Acoustical deterrents in marine mammal conflicts with fisheries. Oregon State Univ. Publ. ORESU-W-86-001.

A joint study by researchers from the Hubbs-Sea World Research Institute and California Fish and Game in collecting physical measurements for the three models of an "acoustic harassment device" (AHD) and three different explosive devices including seal bombs. The devices are used by fishermen to scare sea lions away from nets and sport fishing boats. One of the few available studies in underwater sound measurements of seal-bomb explosions.

Bell, W.B. 1972. Animal response to sonic boom. J. Acoust. Soc. Am. 51(2):758-765.

Animals' most common reaction to sonic boom is a "startle" response. The author concluded that most animals react to sonic booms in a way similar to those exposed to low-flying subsonic aircraft, helicopters and sudden noises. Author reported that sonic booms had no effects on hatchability of eggs. However, he blamed mass hatching failure of sooty tern eggs in 1969 (Dry Tortugas) on physical damage from low-flying-supersonic aircraft.

Bond, J. 1970. Effects of noise on the physiology and behavior of farm-raised animals. Pp 295-306. In: Welch, B.L. and A.S. Welch (eds.), *Physiological effects of noise*. Plenum Press, NY.

Bond claims that sudden noise affected milk production more than did sonic booms. Reactions of dairy and beef cattle were minimal. No evidence of distress was noticeable in pigs exposed to noise of 100-120 dB. Minks were not affected by sonic booms.

Bond, J. 1971. Noise: its effect on the physiology and behavior of animals. *Agric. Sci. Rev.* 9(4):1-10.

The report reviews 21 research studies on the effect of sonic booms and aircraft on the behavior and productivity of farm-raised animals. These studies were initiated to collect reliable information on which to base legal rulings on claims levied against the Air Force for damages caused by aircraft flying over animal installations. The author stresses planned researches to provide concrete answers concerning the effect of sonic booms on farm-raised and wild animals. Studies in this report included those from in and outside the United States.

Bond, J., C.F. Winchester, L.E. Campbell and J.C. Webb. 1963. Effects of loud sounds on the physiology and behavior of swine. *U.S.D.A. Tech. Bull.* No. 1280.

Swine were exposed to aircraft noise of 100-120 dB 12 hours daily three days before farrowing and continuing until their piglets were weaned to determine any harmful effects on reproduction. The number of pigs farrowed and those survived were not effected by noise.

Borg, E. 1981. Physiological and pathogenic effects of sound. In: *The inner ear and hyperbaric conditions: An electrophysiological and morphological study*. *Acta Oto-Laryngol. Suppl.* 381.

Although sound gives "short duration reactions" in rats, long-term effects can be found in relation to content, risky actions, or masking. Noise exposure can cause changes in the blood flow, heart rate, and hormonal systems.

Buckley, J.P. and H.H. Smookler. 1970. Cardiovascular and biochemical effects of chronic intermittent neurogenic stimulation. Pp 75-84. In: Welch, B.L. and A.S. Welch (eds.), *Physiological effects of noise*. Plenum Press, NY.

The investigators exposed rats to noise (100 dB), visual (light) and motion (cage oscillation, rate of 140/min.) stimuli. The authors concluded that stress syndrome is triggered by activation of the central sympathetic activity and the anterior pituitary adrenal cortical axis.

Busnel, R.G. 1968. Acoustic communication. Part III. Some mechanism of communication. Pp 127-153. In: Sebeok, T.A. (ed.), Animal Communication. Indiana University Press, London.

The author discusses the hierarchical position of acoustic signaling, transmission channel, and background noise in communication. The message, its content, destination, and codification was also discussed.

Busnel, R.G. and A.G. Lehamann. 1978. Infrasound and sound: differentiation of their psychophysiological effects through use of genetically deaf animals. J. Acoust. Soc. Am. 63(3): 974-977.

The investigators exposed normal and deaf mice to noise of 60-115 dB at 5-10,000 Hz for two hours and then had the animals tested for swimming time in a water tank. Noise 60-80 dB, at high frequency (500-10,000 Hz) was associated with reduced swimming time from 25-50% for mice with normal hearing, but had no effect on deaf mice. Noise, 160-115 dB, at low frequency (6-50 Hz) was associated with reduced swimming time of both hearing and deaf mice. The experiment demonstrated that infrasonic sounds can be transmitted through visceral and bone pathways and be audible to genetically deaf mice.

Busnel, M.C. and D. Molin. 1978. Preliminary results of the effects of noise on gestating female mice and their pups. Pp 209-248. In: Fletcher, J.L. and R.G. Busnel (eds.), Effects of noise on wildlife. Academic Press, NY.

This study was carried out on 470 female mice, each with six litters amounting to about 17,000 pups. Mice were exposed to chronic urban noise, horizontal "shaking," and crowding for six months. Deaf subline as well as non-deaf subline of the same mouse strain were used. Investigators found that two stressors were more effective than one. Gestational regularity, weight of pups, and number of malformations was greater in the noise-plus-shaking-and-crowding than noise-alone group.

Carole, A.K., R.O. Cook and R.E. Staples. 1976. Teratogenic potential of noise in mice and rats. Toxicol. Appl. Pharmacol. 36:239-245.

White noise of 100 dB at 20-20,000 Hz produces fetotoxic and maternal effects in mice, but not rats. Level of noise had no teratogenic effects in either species.

Casady, R.B. and R.P. Lehamann. 1967. Responses of farm animals to sonic booms. Sonic boom experiments at Edwards Air Force Base. Annex H. U.S. Department of Agriculture. Agric. Res. Ser., Anim. Husbandry Res. Div., MD.

The investigators subjected a race horse, two beef feeder lots, two turkey and two chicken ranches, a sheep ranch, a commercial dairy, and a pheasant daily to sonic booms and low-level overflights of Air Force aircraft. The animals did not respond to sonic booms and their reactions were more pronounced when exposed to low-flying aircraft. Animals' reactions to low-flying aircraft were similar in magnitude to those resulting from flying objects and presence of strangers or moving objects. Avian species were more responsive than mammals. The authors warned that the tested animals had been exposed to sonic booms previously and may be acclimated to the noise.

Coe, J.M. and W.E. Stuntz. 1980. Passive behavior by the spotted dolphin, Stenella attenuata, in tuna purse-seine nets. Fish. Bull., U.S. 78:535-537.

This report describes the purse seining method of catching yellowfin tuna associated with dolphins in the eastern tropical Pacific. The "passive" behavior displayed by spotted dolphins encircled in the net was observed and compared to observations by Norris et al. 1978.

Coe, J.M., D.B. Holts and R.W. Butler. 1972. Guidelines for reducing porpoise mortality in tuna purse seining. U.S. Dept. Commer., NOAA Tech. Rep. NOAA-TM-NMFS-SWFC-13. 17p.

When "porpoise fishing" for yellowfin tuna and other species, dolphins are entangled in folds and canopies of the net and die. Configuration of the net during a set is the major determinant in the number of dolphins killed. Deepening the net by towing with speedboats reduce net canopies and prevent net collapse. Skill vessel maneuvers is also effective in minimizing mechanical failures on net configuration that can result in high dolphin mortality. The use of small mesh safety panels and aprons also reduces dolphin killed during backdown. The investigators believed that better understanding in the dynamics of backdown procedures reduce dolphin mortality. However, it is the skill and motivation of captain and crew which are the final determinants in lowering mortality during a set.

Cottureau, P. 1978. Effect of sonic boom from aircraft on wildlife and animal husbandry. Pp 63-79. In: Fletcher, J.L. and R.G. Busnel (eds.), Effects of Noise on wildlife. Academic Press Inc., NY.

All domesticated farm and wild animals show "startle" behavior when subjected to sonic boom for the first time. These reactions are slight and the animals are usually able to adapt readily to further exposures. Poutry are known to show the most pronounced responses to sonic booms.

Davis, P. 1967. Ravens' response to sonic boom. British Birds 60:370-371.

This is a report on the response of ravens (Corvus corax) to sonic booms by author in central Wales January 10, 1967. In this report, the author documented the reaction of 62-70 ravens to sonic boom in a remote upland area of Cardigan-Carmarthen County boundary when startled and shattered by a loud sonic boom from a jet aircraft. The birds were agitated and spent time flying wildly chasing each other and often settled briefly on rocks making a great deal of noise. In 10 minutes, they dispersed and the calling died down. About 30 of the birds continued to soar over a hill 30 minutes after the disturbance.

Dufour, P.A. 1980. Effects of noise on wildlife and other animals: review of research since 1971. National Technical Information Service, NOAA Rep. No. 550/9-80-100. 97p.

An update to the 1971 study by John L. Fletcher. This is a comprehensive report on noise as a "stressor" on domestic, wild, and laboratory animals. The study is subdivided into taxonomic groups and individual species. The section on domestic animals discusses auditory, physiological, and behavioral noise effects on swine, cattle, sheep, horses, mink, and poultry. The wildlife section covers effects of noise on physiology, hearing, and masking on mammals, birds, reptiles, amphibians and insects. The section on laboratory animals discusses auditory damage and physiological noise effects on the cardiovascular, neuroendocrine, biochemical, pulmonary, reproductive, and immune systems.

Ellis, D.H., J.G. Goodwin, Jr. and J.R. Hunt. 1978. Wildlife and electric power transmission. Pp. 81-104. In: Fletcher, J.L. and R.G. Busnel (eds.), Effects of Noise on Wildlife. Academic Press Inc., NY.

Study considers wildlife interactions with powerline construction. Emphasis was on animal displacement during construction, avoidance of powerlines, mortality due to powerlines and support structures, possible effects of line corona and electrochemical oxidants, benefits due to presence of support towers, and negative effects of wildlife on transmission systems.

Evans, W.E. 1982. Preliminary evaluation of perception and detection of man-made noise (LNG source) by selected marine mammals. HSWRI Tech. Rep. No. 82-142. 10p.

A testimonial report to the National Energy Board of Canada on possible acoustic effects of Arctic Pilot Project LNG ice-breaker noise on marine mammals. Author testified that animals 40 km away from LNG sound source would barely perceive the noise, but those within this range would. He also pointed out that it would be very difficult to tell whether this type noise would have a damaging effect on marine mammals. He did, however, expressed concern in noise with sudden changes in frequency or intensity rather than magnitude since LNG sounds at about 1 kHz produce sound levels of 143-180 dB (re 1 μ Pa) at extremely short ranges. Author was unsure if LNG sound levels would be of any greater detriment to these animals than masking from natural sources.

Fell, R.D., E.J. Ellis and D.R. Griffith. 1976. Thyroid responses to acoustic stimulation. Environ. Res. 12:208-213.

The investigators exposed male and female rats to A-weighted noise of 95 dB at 1,000 Hz in 15 minute intervals eight hours a day for 12 weeks. Weight gain in males decreased during week six of the experiment and stayed low for the remaining six weeks. Weight gain in females decreased during week two and remain lower than the controls.

Fink, G.B. and W.B. Iturrian. 1970. Influence of age, auditory conditioning, and environmental noise on sound-induced seizure threshold in mice. Pp 211-226. In: Welch, B.L. and A. S. Welch (eds.), Physiological effects of noise. Plenum Press, NY.

Investigators reported that sound-induced convulsions can be obtained in resistant strains of mice (e.g., CF#1, C57B1/6, SJL, CBA) by selecting proper age of specimen used, audio-conditioning, and control of the sensitization process. The young mice are more sensitive to environmental factors and it is possible that intense auditory stimuli in a critical period disrupts neurological maturation in these animals. All mice are susceptible to convulsions induced electrically or chemically. Sound, however, is the most used sensory stimulus evoking seizures in mice. Factors found to determine audiogenic seizure susceptible in mice are: age, audition, behavioral situations, environmental influences, hormones, and nutrition. Of the above, age influenced the survivability of a sound exposed mice.

Forster, F.M. 1970. Human studies of epileptic seizures induced by sound and their conditioned extinction. Pp 151-158. In: Welch, B.L. and A.S. Welch (eds.), Physiological effects of noise. Plenum Press, NY.

Approximately 6.5% of epileptic patients are affected by sound stimulation. The most common is called "startle" or "acoustico-motor epilepsy." Exposure to sudden noise will evoke a seizure, usually akinetic and with loss of consciousness.

Friedman, M., S.O. Byers and A.E. Brown. 1967. Plasma lipid responses of rats and rabbits to an auditory stimulus. Am. J. Physiol. 212:1174-78.

Rats exposed to noise of 102-114 dB at 200 Hz intermittently for 21 days exhibited increased post-prandial plasma triglyceride. Rabbits exposed to similar sound stimulus for 70 days exhibited higher blood-cholesterol and atherosclerosis than control animals on the same diet.

Fuller, J.L. and R.L. Collins. 1970. Genetic and temporal characteristics of audiogenic seizures in mice. Pp 203-210. In: Welch, B.L. and A.S. Welch (eds.), Physiological effects of noise. Plenum Press, NY.

Susceptibility to sound varies with age and with previous exposure during a critical age (priming).

Gerber, W.F. 1970. Cardiovascular and teratogenic effects of chronic intermittent noise stress. Pp 85-90. In: Welch, B.L. and A.S. Welch (eds.), Physiological effects of noise. Plenum Press, NY.

The investigator reported that when noise stress is received by the auditory apparatus of pregnant rats, various higher brain centers are activated (e.g. hypothalamus and hypophysis). This in turn will stimulate the adrenal cortex and medulla to release their hormones. A combination of hormones and increased peripheral-vessel resistance in the adult raises blood pressure and decreases uterine blood flow which in turn interferes with proper gaseous, nutrient, and waste-product interchange between fetus and mother. The relative hypoxemia along with the catecholamines released by maternal stress affect fetal normal blood flow and other biochemical pathways resulting in improper organogenesis in fetus.

Gerber, W.F., T.A. Anderson and B. Van Dyne. 1966. Physiologic response of the albino rat to chronic noise stress. Arch. Environ. Health 12:751-754.

Exposure of albino rats to high level noise of 20-25 kHz resulted in eosinopenia and decreased level of ascorbic acid in the blood plasma. The investigators also noted that the elevation of serum cholesterol and depression in the amounts of adrenal ascorbic acid existed many days following audiogenic stress.

Gray, J.A. 1982. The neuropsychology of anxiety: an inquiry into the functions of the septohippocampal system. Clarendon Press, Oxford. 316p.

Anxiety is an analogue of depression. Symptoms of anxiety and depression co-exist more often than either is found in a pure state. Increased activity in the septohippocampal system caused anxiety, and helplessness corresponded to depression. This sequence of events implies that under prolonged stress, subject will be dominated by anxiety. Symptoms are motor retardation and weight loss.

Greaves, J.H. and F.P. Rowe. 1969. Responses of confined rodent populations to an ultrasound generator. J. Wildl. Manag. 33:409-417.

A study on responses of wild rats (Rattus norvegicus) and wild house mice (Mus musculus) when exposed for 76 and 81 days to a unit generating ultrasound pulse, respectively. Except for two occasions, (day 10, rats; and day 18, mice), the animals failed to venture out of their sound-proofed compartments to one in which the sound was generated. This compartment, however, was flooded readily by the animals when the ultrasound generator was switched off. The investigators later observed that when the animals became very hungry, they ventured boldly into the sound compartment for food and water even when the unit was on.

Gregory, B.F. and W.B. Iturrian. 1970. Influence of age, auditory conditioning, and environmental noise on sound-induced seizure threshold in mice. Pp 211-226. In: Welch, B.L. and A.S. Welch (eds.), Physiological effects of noise. Plenum Press, NY.

The investigators concluded that determinant factors affecting convulsion behavior in rats were: Genetic constitution, age, hormones, nutrition, audition, environmental influences, and behavioral situations.

Griffiths, W.J., Jr. 1948. Effect of adrenalectomy on incidence of audiogenic seizures among domestic and wild rats. J. Comp. Physiol. Psychol. 49:303-312.

Investigators found that inactivity and non-emotionality in wild rats were not factors in determining susceptibility to seizure.

Groh, L.S. 1965. The effects of two litter sizes and two levels of noise during infancy upon the adult behavior of the white rat. Diss. Abstr. 27:598-599.

The author experimented with the effect of white-noise and crowded living conditions in rat litters. Four groups of 20 rat pups were raised to 60 days of age. Pups raised in litters of 13 weighed less and had larger adrenal glands than those in litters of 3. Those raised in a sound-proofed box were faster learners than those in a noisy (50-60 dB) room. Pups raised in large litters in a sound-proofed box and those in small litters in the noisy room showed greater increase in heart rate in response to an electric shock and were less active. Noise and competition for food in large litters made rats more anxious.

Hanson, J.D., M.E. Larson and C.T. Snowdon. 1976. The effects of controls over high intensity noise on plasma cortisol levels in Rhesus monkeys. Behav. Biol. 16(3):333-340.

Rhesus monkeys subjected to industrial and traffic noise of 100 dB and had loss control over sound exhibited increase aggressive behavior while those with no control showed less social contact with their peers. The investigators also measured plasma cortisol levels in these animals after exposure to high intensity noise under the following four conditions: 1) control over noise, 2) loss of control over noise, 3) no control over noise, and 4) and no noise. Animals that lost control or had no control over noise had significantly elevated plasma cortisol levels.

Harbers, L.H., D.R. Ames, A.B. Davis and M.B. Ahmed. 1975. Digestive responses of sheep to auditory stimuli. J. Anim. Sci. 41:654-658.

Yearling wethers were exposed to white noise, music and intermittent miscellaneous sounds (IMS) of 75-100 dB by the investigators when studying metabolism and rumen motility. Animals ate less ($P < .05$) when subjected to ambient noise of 48 dB. There was increase water intake ($P < .05$), metabolizable energy of the ration ($P < .01$) and improved nutrient digestibilities ($P < .03$) when exposed to IMS 75-100 dB. Nitrogen retention was not affected by sound intensity.

Hepworth, J.L. 1966. Hematology of Sigmodon hispidus: average parameters compared with those under induced stresses. Unpubl. Ph.D. Diss. Oklahoma State Univ., Stillwater.

Sexually active male rats had low survival rates and were constantly in conflict. Males' blood also prone to clotting. Survival of females under induced stress was significantly higher than males.

Hooker, B.I. 1968. Birds. Communication in selected groups. Part IV. Pp 311-337. In: Sebeok, T.A. (ed.), Animal Communication. Indiana Univ. Press, Bloomington, London.

Study in vocal communication in various species of birds. Functions of songs were studied and explanations of duet singing and mimicry in birds discussed.

Hrubes, V. and V. Benes. 1965. The influence of repeated noise stress on rats. Acta Biol. Med. Ger. 15(5):592-596.

The investigators found that repeated noise stress on rats increased secretion of catecholamines and free fatty acid in the blood plasma. There was also significant weight increase in suprarenals and growth inhibition in exposed rats.

Ishii, H. and K. Yokobori. 1960. Experimental studies on teratogenic activity of noise stimulation. Gunma J. Med. Sci. 9:153-167.

Noise stimulation is teratogenic at about 100 dB. Stressor effect may be traced to the stimulation of the adrenals by ATCH (pituitary) to secrete large amounts of cortisone.

Jensen, M.M. and A.F. Rasmussen, Jr. 1970. Audiogenic stress and susceptibility to infection. Pp 7-19. In: Welch, B.L. and A.S. Welch (eds.), Physiological effects of noise. Plenum Press, NY.

Mice exposed to sound intensities of 120 dB (800 Hz) showed evidence of leukopenia followed by leukocytosis. Mice inoculated with stomatitis virus before exposure to sound were more susceptible to the infection, while those inoculated after exposure were more resistant. Mice infected with polyoma virus and then exposed to noise stress developed more tumors.

Jurtshuk, P., A.S. Weltman and A.M. Sackler. 1951. Biochemical response of rats to auditory stress. *Sci.* 129:1424-25.

Female albino Wister rats weighing 145-195 g, paired by weight, were subjected to noise 100 dB at 120 Hz, one minute daily for 11 days, and five minutes daily for 15 days. The study shows that blood glutathione levels decreased significantly in both test groups. There was also an increase in adrenal weights and ascorbic acid, as well as a decrease in total adrenal cholesterol in the test rats.

Kenneth, R.H. and R.E. Bowman. 1970. Acoustic priming of audiogenic seizures in mice. Pp 185-201. In: Welch, B.L. and A.S. Welch (eds.), *Physiological effects of noise*. Plenum Press, NY.

The study gives support to the idea that prior exposure to intense auditory stimulation can induce susceptibility to seizure in mice. The four stages of autogenic seizures (wild running, "rapid jerks" by all four limbs [clonic], hind limbs extended backward [tonic], and death [respiratory failure]) are discussed in detail. The investigators concluded that priming is maximally effective between days 16 and 19 postpartum. Age is recognized as the controlling factor and susceptibility to seizure is a genetic function.

Kimmel, C.A., R.O. Cook and R.E. Staples. 1976. Teratogenic potential of noise in mice and rats. *Toxicol. Appl. Pharmacol.* 36:239-245.

A study on the effects of noise on the developing embryo of rats and mice. Experiment I was designed to determine whether background noise plays a role in producing malformations in the animals. The observed animals were exposed to A-weighted noise 30-45 dB, and were housed in a controlled sound-proofed chamber. The control group was housed in a regular room where noise levels were 50-60 dB. On day 18 of gestation, the animals were examined for weight gain. Mice raised in the sound proof chamber gain less weight than controls. Experiment II measured maternal and embryonic responses of mice exposed on days 7-11 or 11-14 and rats on days 6-15 to white noise 100 dB six minutes of each half hour. Mice exposed on days 11-14 during pregnancy gained significantly less weight and had high resorption. Rats exposed to the same noise levels had decreased maternal weight gain and no developmental toxins present in the system.

Klein, D.R. 1971. Reaction of reindeer to obstructions and disturbances. Sci. 173:393-398.

Modern use of snowmobiles for transportation and herding in Scandinavia disturb reindeer. Besides noise, large amounts of industrial wastes in the atmosphere fall out in rain and snow. Disruption in movements of these animals in Norway has been associated with noise from highway and railroad construction.

Krushinsky, L.V., L.N. Molodkina, D.A. Fless, L.P. Dobrokhotova, A.P. Steshenko, A.F. Semiokhina, Z.A. Zorina, and L. G. Romanova. 1970. The functional state of the brain during sonic stimulation. Pp 159-183. In: Welch, B.L. and A.S. Welch (eds.), Physiological effects of noise. Plenum Press, NY.

Study describes the types of seizures induced by an acoustic stimulus. Investigators also examined physiological mechanisms, established pathological consequences, and investigated protective brain mechanism against noise. They found that sonic stimulation may lead to severe pathological disturbances (convulsion, myoclonic hyperkinesias, shock, and cerebral hemorrhages). They concluded that the nervous system has more than one line of defense in preventing convulsions.

Lazovik, A.D. and R.A. Patton. 1947. The relative effectiveness of auditory stimulation and motivational stress in precipitating convulsions associated with magnesium deficiency. J. Comp. Physiol. Psychol. 18(40):191-202.

Although magnesium deprivation induced convulsive seizure in 17 of 18 rats observed, those exposed to noise (air-blast) also showed very high incidence of seizures. Convulsive seizures were found not to be associated with forced reaction in rats. Investigators concluded that "conflict" was ineffective in inducing seizures.

Lee, J.M., Jr. and D.B. Griffith. 1978. Transmission line audible noise and wildlife. Pp 105-168. In: Fletcher, J.L. and R.G. Busnel (eds.), Effects of noise on wildlife. Academic Press, Inc., NY.

The study addresses characteristics of transmission-line-audible noise and its effects on human environment and wildlife.

Lehmann, A.G. 1970. Psychopharmacology of the response to noise, with special reference to audiogenic seizure in mice. Pp 227-257. In: Welch, B.L. and A.S. Welch (eds.), Physiological effects of noise. Plenum Press, NY.

The author concluded that intense noise can affect physiological functions such as circulatory, reproductive, and endocrine systems. It can cause loss of sleep and susceptibility to infection. The most harmful effect of noise on humans and animals is its influence on the central and sympathetic nervous systems.

Lehmann, A.G. and R.G. Busnel. 1963. A study of the audiogenic seizure. Pp 244-274. In: R.G. Busnel (ed.), Acoustic behavior of animals. Elsevier, Amsterdam.

Audiogenic seizure is hypothesized to originate from a peripheral excitation and spread through the auditory apparatus and onto the central nervous system. Diets deficient of substances which are considered cofactors of specific enzymetic reactions (e.g., glycolytic and tricarboic acid) increase the severity of seizures. The report discusses the four phases of seizure from acoustic stimulation. It also covers physical characteristics, genetic aspects, effect of temperature, and the role of the ear in audiogenic seizure.

Lockett, M.F. 1970. Effects of sound on endocrine function and electrolyte excretion. Pp 21-41. In: Welch, B.L. and A.S. Welch (eds.), Physiological effects of sound. Plenum Press, NY.

Anxiety, loud sound, intense light, immobilization, forced exercise, surgery, cold, and other stressful agents increase secretion of ACTH. This process is neurohumoral, and is mediated through the central nervous system. Elevation of ACTH causes an increase in secretion of adrenal corticoids which is characteristic of an animal (rat, human, or monkey) under stress. Intensity of sound needed to produce seizures is 90-134 dB at 4-80 kHz. All animals, whether susceptible or not to seizure, respond to noise by release of epinephrine.

Lukas, J.S. and K.D. Kryter. 1970. Awakening effects of simulated sonic booms and subsonic aircraft noise. Pp 283-293. In: Welch, B.L. and A.S. Welch (eds.), Physiological effects of noise. Plenum Press, NY.

Investigators described a sonic-boom simulator and subsonic-aircraft noise and their effects on sleeping humans. Subjects were unable to adapt to the noise during sleep; however, were adaptable to subsonic-aircraft noise.

Luz, G. and J.B. Smith. 1976. Reaction of Pronghorn antelope to helicopter overflight. J. Acoust. Soc. Am. 59:1514-15.

Reactions of Pronghorn antelope were observed from a helicopter hovering at 400 ft with a slant range of 3,000 ft. Investigators reported muscle tensing and interruption of grazing in the herd. Strong reaction (e.g. running) started when the craft was hovering at 150 with a slant of 500 ft. The estimated noise levels eliciting no reaction and strong reaction were approximately 60 and 70 dB, respectively.

Lynch, T.E. and D.W. Speake. 1978. Eastern wild turkey behavioral responses induced by sonic boom. Pp 47-61. In: Fletcher, J.L. and R.G. Busnel (eds.), Effects of Noise on Wildlife. Academic Press Inc., NY.

The investigators equipped wild turkey hens with 164 MHz transmitters which were located by telemetric triangulation. Four of the experimental hens were subjected to both real and simulated sonic booms. Those with young were exposed to simulated sonic boom only. Sonic booms did not affect productivity in the exposed turkey hens.

Malar, T. and H. Kleerekoper. 1968. Observations on some effects of sound intensity on locomotor patterns of naive goldfish. Am. Zool. 8(4):741-742.

An analysis of locomotor patterns of a goldfish subjected to noise of 60-120 dB (re 1 μ Pa) in a 5x5 m tank. The experiment showed that distribution of angles of turn changes significantly at levels 80 dB. Authors concluded that sound can effectively modify the locomotor pattern of fish. Investigators also found that the preferred direction of turning did not depend on sound exposure.

Myrberg, A.A., Jr. 1978. Ocean noise and the behavior of marine animals: relationships and implications. Pp 169-208. In: Fletcher, J.L. and R.G. Bushnel (eds.), Effect of noise on wildlife. Academic Press Inc., NY.

The investigator concluded that an acoustical system can, and does, provide an animal appropriate information relative to food, competitors, predators, and potential mates. However, he expressed concern that ambient noise, especially in the shallow, coastal waters of the world's oceans, may become more of a communication problem because of masking.

Myrick, A.C., Jr. 1988. Is tissue resorption and replacement in permanent teeth of mammals caused by stress-induced hypocalcemia? Pp 379-389. In: Davidovitch, Z. (ed.), The Biological Mechanisms of Tooth Eruption and Root Resorption. EBSCO Media, Birmingham, AL.

The investigator examined systemic dental resorption and repair in teeth of humans, dolphins, bobcat, black bears, elk and other mammals which could be attributed to stressors. Two general models on hypocalcemic responses to stressors are presented.

Nawrot, P.S., R.O. Cook and R.E. Staples. 1980. Embryotoxicity of various noise stimuli in the mouse. Teratol. 22:279-289.

There was decreased pregnancy rate: significant embryo-lethal effects occurred in groups exposed during 1-6 days gestation, and significant fetolethal effects occurred in groups exposed during 6-15 days gestation. Sound in combination with "startle" noise was more effective in producing fetal weight loss from days 1-6 of gestation.

Nayfield, K.C. and E.L. Besch. 1981. Comparative responses of rabbits and rats to elevated noise. Lab. Anim. Sci. 31(4): 386-390.

Animals were exposed to white noise of 107-112 dB compared to control of 60 dB. Rabbits and rats displayed increased adrenal weights, rabbits had decreased spleen and thymus weights, rats increased leukocyte and eosinopenia. Rats also exhibited decreased food intake. Authors supports the belief that weight of organs provide best information that elevated noise is stressful to the animals.

Norris, K.S., W.E. Stuntz, and W. Rogers. 1978. The behavior of porpoises and tuna in the eastern tropical Pacific yellowfin tuna fishery-preliminary studies. U.S. Dep. Commer., NOAA Tech Memo., NOAA-TM-NMFS-SWFC-70. 86p.

A study in the behavior of purse-seine-captured spotted and spinner dolphins when fishing for yellowfin tuna in the eastern tropical Pacific. Observations on dolphins included behavioral patterns of the animals on the surface and underwater prior to and during the chase and when encircled. Individual animal behavior and school behavior are discussed. Also included is a discussion of overall movement patterns of captured schools.

Ogle, C.W and M.F. Lockett. 1966. The release of neurohypophysial hormone by sound. J. Endocrin. 36:281-290.

The experimental rats exposed to thunderclap recordings of 98-100 dB at 150 Hz had increased urinary excretion of water, sodium and potassium. This is attributed to release of oxytocin. The effects of sound in the animals was absent after adrenalectomy and denervation of kidneys.

Parker, J.B. and N.D. Bayley. 1960. Investigations on effects of aircraft sound on milk production of dairy cattle 1957-58. U.S. Dept. Agricul. Res. Serv., Anim. Hus. Res. Div. 22p.

A report on measurable effects of sonic-boom noise on milk production by dairy herds located in the vicinity of eight Air Force Bases. The information was obtained from the 182 herds pasturing in areas within three miles of airfields for jet aircrafts.

Perrin, E.V.D., K. Benirschke and W.F. Perrin. 1989. Monstrous dolphins malformations in marine mammals. Teratol. 39(472): 51.

This is a one-page synopsis reporting results of a brief study on malformations in cetaceans. The investigators assumed that conditions may be linked to xenobiotic contaminants, which may include stress.

Perrin, W.F. 1969. Using porpoise to catch tuna. World Fishing 18(6):42-45.

In locating and catching schools of yellowfin tuna associated with spotted dolphin Stenella graffmani and spinner dolphin S. longirostris, the purse-seine fishermen in the eastern tropical Pacific had to face the problem of high dolphin mortality in the fishery. Author stressed the need for future technological and biological research on net fishing, relation between tuna and dolphins, and dolphin populations.

Peterson, E.A., J.S. Augenstein, R.S. Hosek, K.J. Klose, K. Manas, J. Bloom, S. Lovett and D.A. Greenberg. 1975. Noise and cardiovascular function in Rhesus monkeys. J. Audit. Res. 15(4):234-251.

Study on cardiovascular responses of Rhesus monkeys to noise. In Experiment I, a semi-restrained animal was exposed to unpredictable and intense noise bursts. The noise caused acute blood pressure adjustments of up to 30% in the animal. These increases became slightly smaller as stimuli were repeated for a period of 30 days. In Experiment II, a different monkey was subjected to recordings of exterior community noise. The blood pressure in the animal stay elevated for 30 days. Results suggest that noise has a profound effect on the cardiovascular system, especially on the blood pressure.

Rosen, S. 1970. Noise, hearing and cardiovascular function. Pp 57-66. In: Welch, B.L. and A.S. Welch (eds.), Physiological effects of noise. Plenum Press, NY.

Noise causes the human body to go into psychic shock, blood vessels constrict, skin pales, pupils dilate, eyes close (one winces), apnea, and involuntary and voluntary muscles tense, gastric secretions decrease and diastolic pressure increases. Adrenalin flows into blood stream causing muscular tension, nervousness, irritability and anxiety.

Sackler, A.M., A.S. Weltman, M. Bradshaw and P. Jurtshuk, Jr. 1959. Endocrine changes due to auditory stress. Acta Endocrinol. 31:405-418.

Rats exposed to noise of 110 dB at 375-500 Hz exhibited adrenal hyperplasia (abnormal increase in cells), and reduction of ovarian activity and weight. There was vascularity of the uterus and loss in liver weight. Appetite was affected and food consumption reduced.

Scott, J.P. 1968. Observation. Techniques of Study. Part II. Pp 17-30. In: Sebeok, T.A. (ed.), Animal Communication. Indiana Univ. Press, Bloomington, London.

The author discusses visual, auditory, and chemical forms of communications. Tactile stimuli, a restricted and an important form of social behavior in care of young in mammals and a form of communication among insects is also discussed.

Selye, H. 1973. The evolution of the stress concept. Am. Sci. 61:692-699.

The report gives an explanation of the physiological effects, biological consequences and conditions under which stress is harmful to organisms. Author emphasizes that stress arises from the demand to provide the necessary energy to maintain life and to adapt to external conditions. Animals stressed for long periods developed enlarged adrenal glands, reduced thymus, spleen and lymph nodes, and developed deep bleeding ulcers. An acute stress (alarm reaction) could cause death in extreme cases. The investigator also emphasized that a prolonged chronic stress may lead to: loss of immune function, decrease body weight, depression, and abnormal function in organs such as gonads and throid.

Shaw, E.A.G. 1978. Symposium on the effects of noise on wildlife. Pp 1-5. In: Fletcher, J.L. and R.G. Busnel (eds.), Effects of noise on wildlife. Academic Press, NY.

The author discusses noise as a pollutant. However, emphasis is on effects of noise on wildlife communication. Acoustic signals are recognized as the common navigational system used by various species to maintain and established contact with other members of the species and to convey messages such as distress or presence of food.

Sontag, L.W. 1970. Effect of noise during pregnancy upon fetal and subsequent adult behavior. Pp 131-141. In: Welch, B.L. and A.S. Welch (eds.), Physiological effects of noise. Plenum Press, NY.

There is evidence that environment has a major role in shaping the physique, behavior and function in animals, including humans. The fetus is capable of receiving sounds and responds to physiological changes. Mothers in severe emotional states in the later months of pregnancy produce hyperkinetic, uncomfortable, and poorly functioning infants. The behavioral change is usually shown in later years of childhood.

Soom, R., J.G. Bollinger and O.J. Rongstad. 1972. Studying the effects of snowmobile noise on wildlife. Pp 236-241. In: Proceedings of Internoise 72 Symposium, October 4-6. Washington, D.C.

This paper presents results of a research on the effects of snowmobiles on wild rabbits and deer. The two hypothesis tested were: 1) will the noise cause the animals to move outside their normal home and seek shelter until the disturbance stops, and 2) will the animal activities be significantly different in periods when snowmobiles are and are not present? The noise levels made by the snowmobiles in the 4-6 nights of experimentation were 95 dB with median levels of 54-60 dB (A-Weighted). Results show that the rabbits had increased activity and also home range sizes increased significantly when snowmobiles were present; however, none of the deer left their normal home range.

Sprock, C.M., W.E. Howard and F.C. Jacob. 1967. Sound as deterrent to rats and mice. J. Wildl. Manag. 31:729-741.

This study considers the feasibility of using sound to produce an uninhabitable environment for mice and rats or to keep them away from specific areas. Sounds of 110-140 dB at 4-25 kHz were found ineffective in deterring wild and laboratory rats. The investigators also found that rats and mice exposed to continuous tones of <100 dB were not susceptible to audiogenic seizure. Seizure, however, was experienced by male mice of strain DBA/1 Jax when exposed to sounds of >100 dB (none by either sexes in strain C57BL/1 Jax). The study concluded that ultrasonic sounds may never be a deterrent for rats and mice since high-frequency sounds are more directional and do not reflect around corners or transmit through solids. Also, ultrasonic sounds attenuate faster in air and do not project as far as lower sound of same intensity.

Stadelman, W.J. 1958a. Observations with growing chickens on the effects of sounds of varying intensities. Poult. Sci. 37: 776-779.

This investigator exposed broiler chickens to sounds of 110 dB at 2-10 kHz (avg. range, 150-1,200 Hz). He concluded that loss of a pen of broiler chickens to noise is much more likely to occur if they were to be exposed to isolated low-level overflight than to continuous noise in proximity of an airfield. He cautioned that since the observed chickens were exposed to recordings, instead of actual overflight noise, their responses may be different when they are subjected to actual overflight noise, since they will be exposed to both noise and visual stimuli simultaneously.

Stadelman, W.J. 1958b. The effect of sounds of varying intensity on hatchability of chicken eggs. *Poult. Sci.* 37:166-169.

This reports a study on hatchability and quality of eggs subjected to recordings of aircraft-flyover sounds of 96 dB (commercial incubators) and 131 dB (outside incubators), in five of every 20 minutes, 12 hours daily. The author reported that the stressor did not have any effect on the quality of eggs or on hatchability, however, sound levels 115 dB were effective in interrupting overly-broody behavior of 11 of 12 observed hens.

Sze, P.Y. 1970. Neurochemical factors in auditory stimulation and development of susceptibility to audiogenic seizures. Pp 259-269. In: Welch, B.L. and A.S. Welch (eds.), *Physiological effects of noise*. Plenum Press, NY.

Susceptibility to audiogenic seizures observed in higher animals, including man, is genetically selective; but can also be induced by prior auditory input, in a phenomenon called, "priming." Gamma-amino-butyric acid (GABA) is suspected to have a role in the induction of seizure when the animal is primed.

Tamari, I. 1970. Audiogenic stimulation and reproductive function. Pp 117-130. In: Welch, B.L. and A.S. Welch (eds.), *Physiological effects of noise*. Plenum Press, NY.

Rats and rabbits during pre-mating, mating, and post-mating periods were exposed to noise of 100 dB at 3,000-12,000 Hz. There were no changes observed in the behavior of the animals; however, the investigators found disturbances in fertility, productivity, and maintenance of pregnancy. The stimulation of the hypothalamo-pituitary-ovarian axis caused secretion of gonadotrophins (FSH and LH) which led to increase production of oestrogen that interfered with pregnancy.

Tavolga, W.N. 1968. *Fishes. Communication in selected groups. Part IV.* Pp 271-288. In: Sebeok, T.A. (ed.), *Animal Communication*. Indiana Univ. Press. Bloomington, London.

The paper is a comprehensive presentation on the five Levels of communications which exist among animals. It details how an organism can affect other organisms by use of: 1) growth pattern, tropisms, shape and mass as stimuli [vegetative], 2) chemical exudates and other by-product of normal and basic metabolism [tonic], 3) emitters [signal], 4) gestures, facial expressions and vocalization [symbolic], and 5) speech [language] in communication.

Ward, C.O., M.A. Barletta and T. Kaye. 1970. Teratogenic effects of audiogenic stress in albino mice. J. Pharmacol. Sci. 59(11):1661-1662.

Maximum susceptibility of albino mice to noise was observed on days 7-8 during pregnancy. Teratogenic effects included: decreased fetal weight, complete or partial resorption of fetuses, cranial hematoma, dwarfed hind limbs, and tail defects.

Zondek, B. 1964. Effect of auditory stimuli on female reproductive organs. New England obstetrics and gynecology (Trans. 18).

The exposure of rats to cold and light resulted in stimulation of the adrenal and thyroid glands. Auditory stimuli induced blockage and interruption of pregnancy in the stressed animals.

Zondek, B. and I. Tamari. 1964. Effect of audiogenic stimulation on genital function and reproduction. III. Infertility induced by auditory stimuli prior to mating. Acta Endocrinol. Suppl. 90:227-234.

The auditory stimulus used was an electric bell with noise of 3,000-12,000 Hz. The sound-induced stress caused infertility and blockage of pregnancy in rodents.

Zondek, B. and I. Tamari. 1967. Effects of auditory stimuli on reproduction. In: Effects of external stimuli on reproduction. Ciba. Found. Stud. Grp. 26:4-19.

Exposure of rats to noise of 10,000-12,000 Hz from an alarm bell induced changes in the estrous rhythm, caused increase weight of the uterus and ovaries, and increased in number of corpora lutea.

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Table 1

LIST OF KEY WORDS USED IN DATA SEARCH

- I. Behavior, Stress, Mimic, Noise, Telemetry, Sound, Colony, Auditory, Birds, Fish, Marine Mammals, Dolphins, Cetacea, Hoofed Animals, Noxious, Sonic Booms, Expose, Startle, Fright, Intensity, habitat, Grooming, Herd, Food, Migration, Mate, Aggressive, Avoidance, Wildlife, Affect, School, Performance, Domestic Animals, Frequency, Effect, Survival, Response.
- II. Masking, Predator, Prey, Young, Decibel, Frequency, Pressure, White Noise, Phon, Auditory, Signal, Vibration, Communication, Hearing, Acoustic, Receptor, Adapt.
- III. Physical, Functions, Non-auditory, Resistant, Disease, Stimulate, Hormone, Reaction, Exhaustion, Adrenal, Glands, Nervous System, Sympathetic System, Parasympathetic System, Metabolism, Leukocyte, Seizure, Reproduction, Epilepsy, Susceptible, Priming, Fertility, Pregnancy, Fetotoxicity, Resorption, Gestation, Teratology, Malformation, Ovary, Pulmonary, Endocrine, Cell, Pituitary, Thyroid, Blood, Secretion, Cardiovascular, Heart, Rate, Fatty Acids.
- IV. Cows, Chickens, Eggs, Meat, Products, Sheep, Lambs, Milk, Color, Quality, Quantity, Swine.

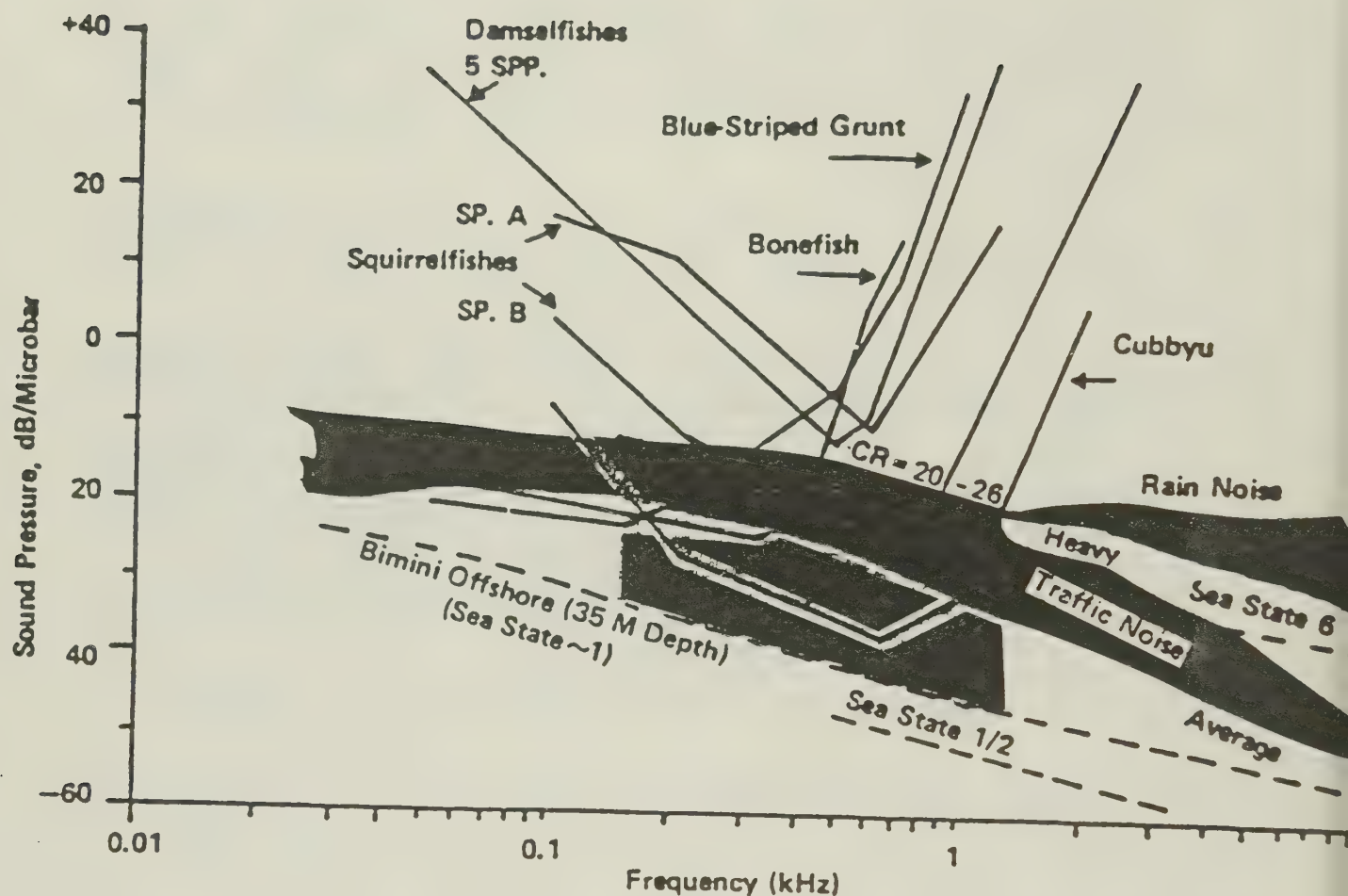


Figure 1. Low frequency ambient noise and its probable masking effect on the hearing abilities of selected marine fishes, whose peak sensitivities are found within that spectrum. The solid area is the region chosen to show the amount of masking that would extend above the arbitrarily chosen level of ambient noise (in spectrum level). The ambient chosen was offshore the island of North Bimini, Bahamas, where all the species resides. Audiograms were selected from various authors (Myrberg 1978; with permission).

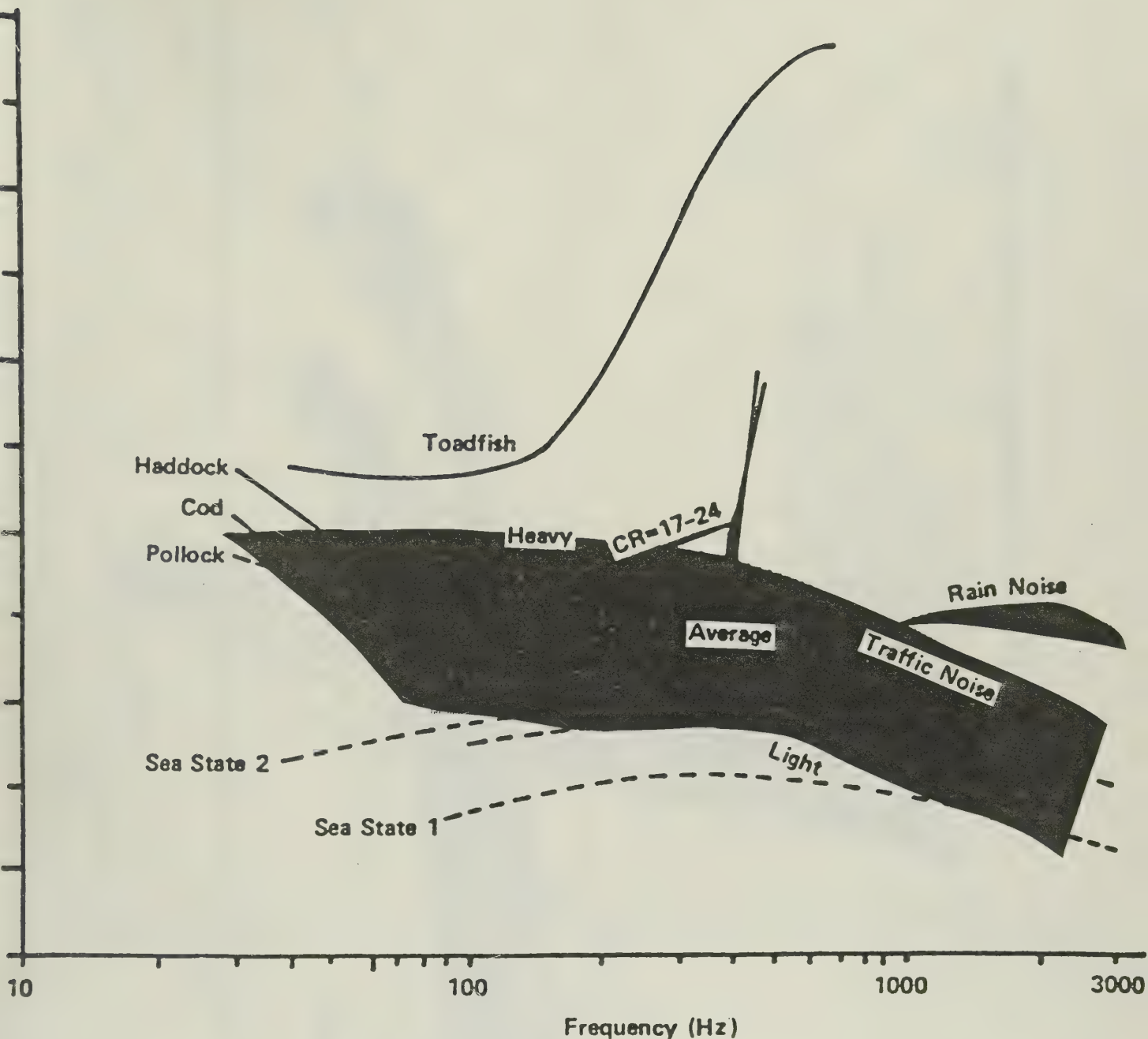


Figure 2. Low frequency ambient noise and its probable masking effect on the hearing abilities of selected marine fishes, whose peak sensitivities are found within that spectrum. The four audiograms shown were determined either totally, or partially, in the field. The solid area is the region chosen to show the amount of masking that would occur above the arbitrarily chosen spectrum levels of sea state (2) and traffic noise (light) for those species possessing the critical ratios (CR) as given (Myrberg 1978; with permission).

Examples of Biological Sources of Sustained Ambient Noise

- A. Croaker Chorus.
- B. Croaker Chorus.
- C. Sea Trout Chorus.
- D. Evening Chorus-Attributed to Sea Urchins
- E. Snapping Shrimp on Spongy Bed.
- F. Snapping Shrimp on Spongy Bed.
- G. Snapping Shrimp on Spongy Bed.

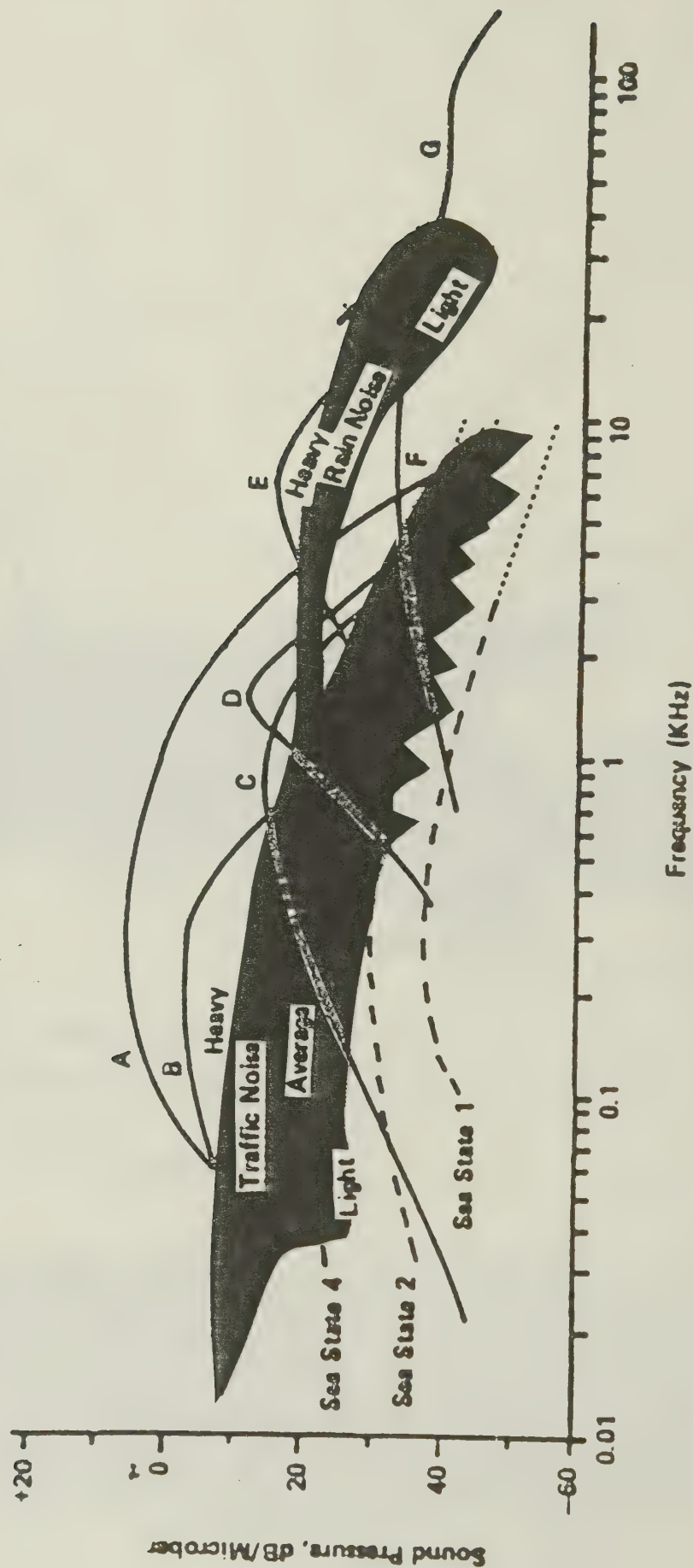


Figure 3. Shallow water (<70 m), ambient noise (spectrum level). Data have been extracted from numerous sources and redrawn. (Myrberg 1978; with permission).

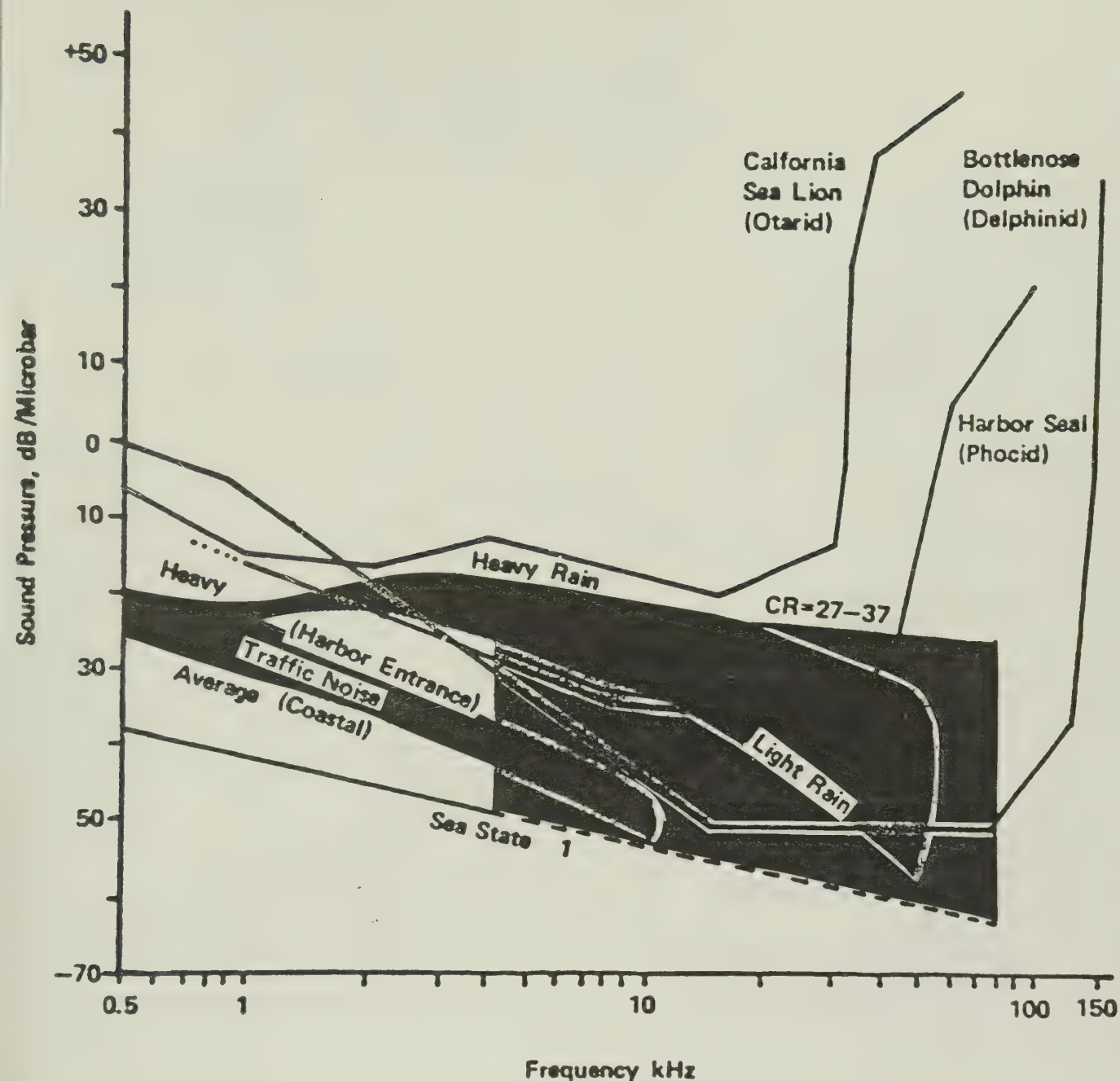
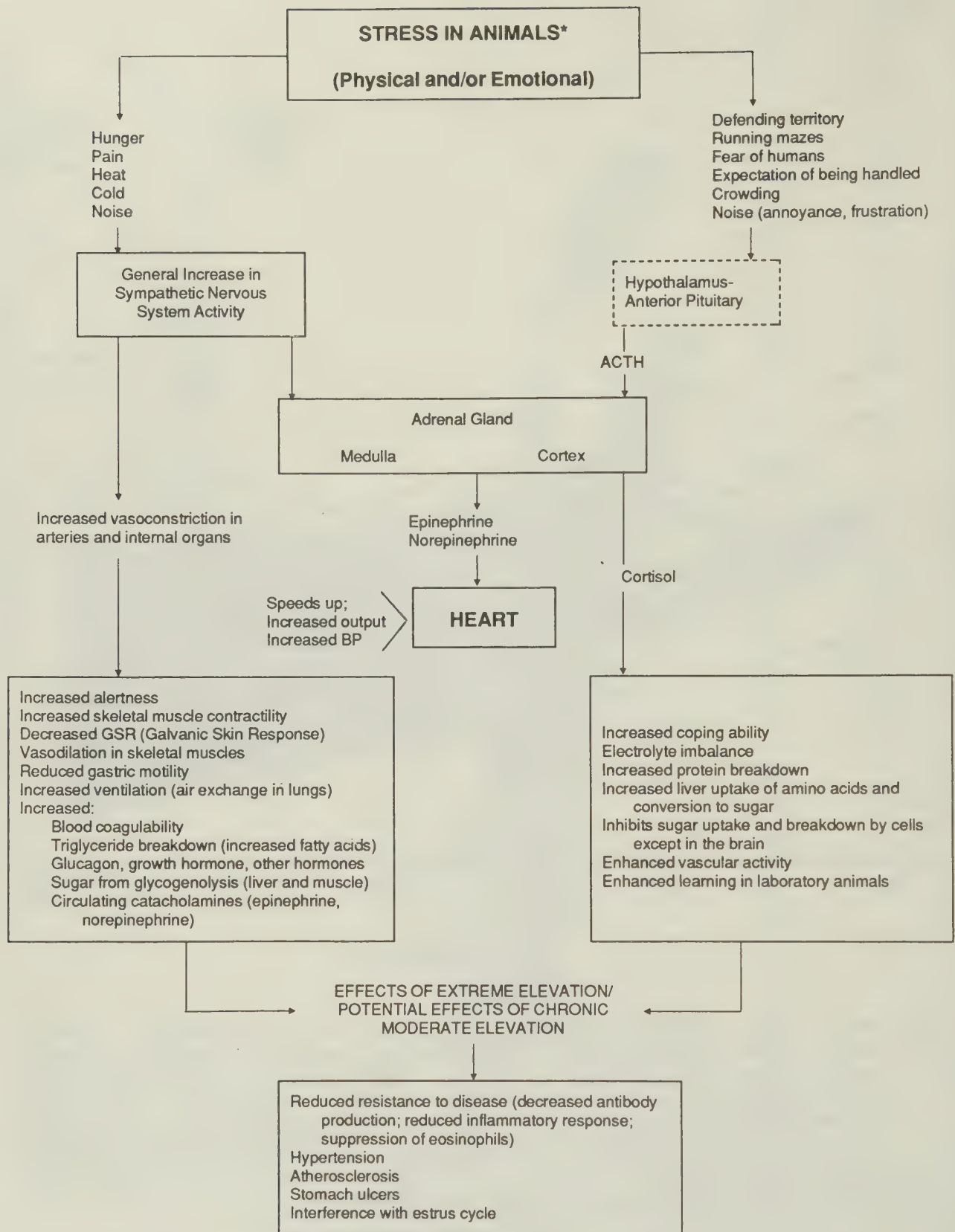


Figure 4. High frequency ambient noise and its probable masking effect on the hearing abilities of selected marine mammals whose peak sensitivities are found within that spectrum. Audiograms were redrawn from several authors. The solid area is the region chosen to show the amount of masking that would extend above the arbitrarily chosen level of ambient noise (in spectrum level) with the critical ratio (CR) provided (Myrberg 1978; with permission).



*Also known as the "fight or flight" response

Figure 5. Stress Responses. Figure redrawn from DUFOUR, 1980 (with permission)



